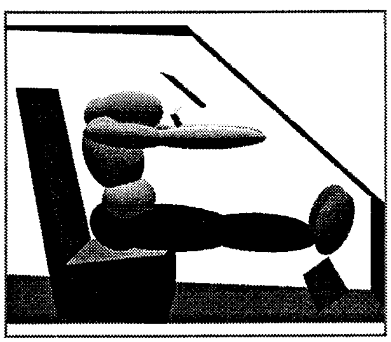
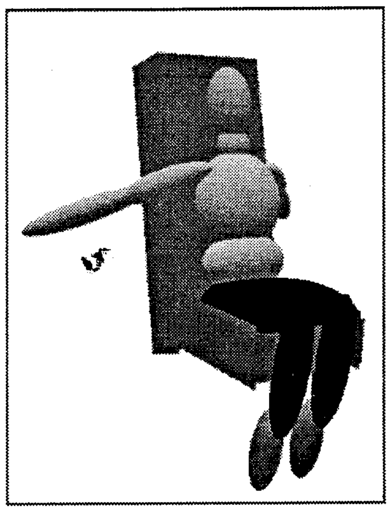
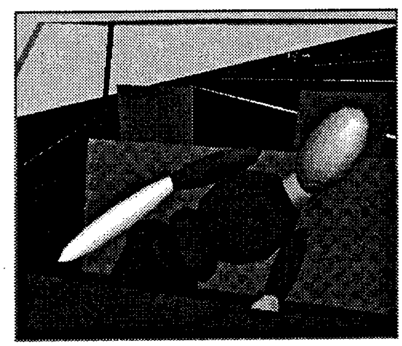
Proceedings of
The 1995 ATB Model Users' Colloquium







June 13-14, 1995
Hope Hotel & Conference Center
Wright-Patterson Air Force Base
Dayton, Ohio, USA

Sponsored by USAF

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The 1995 Articulated Total Body (ATB) Model Users' Colloquium was held at the Wright-Patterson Air Force Base, Dayton OH on 13-14 June 1995. This Colloquium, sponsored by the Armstrong Laboratory (AL), US Department of the Air Force, brought together eighty users of the ATB model and its derivatives (CVS, Cal-3D, and DYNAMAN). The two day conference offered the opportunity to present and exchange the latest ATB modeling techniques and applications. Invited presentations, group discussions, and interactive exercises covered areas like model algorithms, harness belt and airbag modeling, data base development, vehicle and aircraft crashworthiness, dummy and human modeling, and accident reconstruction applications.

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PREFACE

The 1995 Articulated Total Body (ATB) Model Users' Colloquium was held at the Wright-Patterson Air Force Base, Dayton, Ohio on June 13 and 14, 1995. This Colloquium, sponsored by the Armstrong Laboratory (AL), U. S. Department of the Air Force, brought together more than seventy users of the ATB model and its derivatives (CVS, Cal-3D, and DYNAMAN). The two-day conference offered the opportunity to present and exchange the latest ATB modeling techniques and applications. Dr. Thomas J. Moore, Chief of the Biodynamics and Biocommunications Division of AL welcomed the attendees. Eighteen invited presentations, group discussions, and interactive exercises covered areas like model algorithms, harness belt and airbag modeling, data base development, vehicle and aircraft crashworthiness, dummy and real human modeling, and accident reconstruction applications. A formal ATB Users' Group was created to organize regular meetings, to set up bulletin board for exchanging information, and to offer other opportunities.

As this colloquium was designed to be an informal meeting, please do not reference the presentations appearing in these proceedings in the open literature.

The Organizing Committee would like to thank AL and Systems Research Laboratories, Inc. for their support of this colloquium. Many thanks are extended to the speakers for investing the resources needed to prepare the presentations which are contained in this proceeding.

The 1995 ATB Model Users' Colloquium - Organizing Committee:

Dr. Louise Obergefell, *Armstrong Laboratory, USAF*
Dr. Kennerly Digges, *George Washington University*
Mr. Wesley Grimes, *Collision Engineering Associates*
Dr. Nangarajan Rangarajan, *GESAC, Inc.*
Ms. Annette Rizer, *Systems Research Laboratories, Inc.*

June 1995

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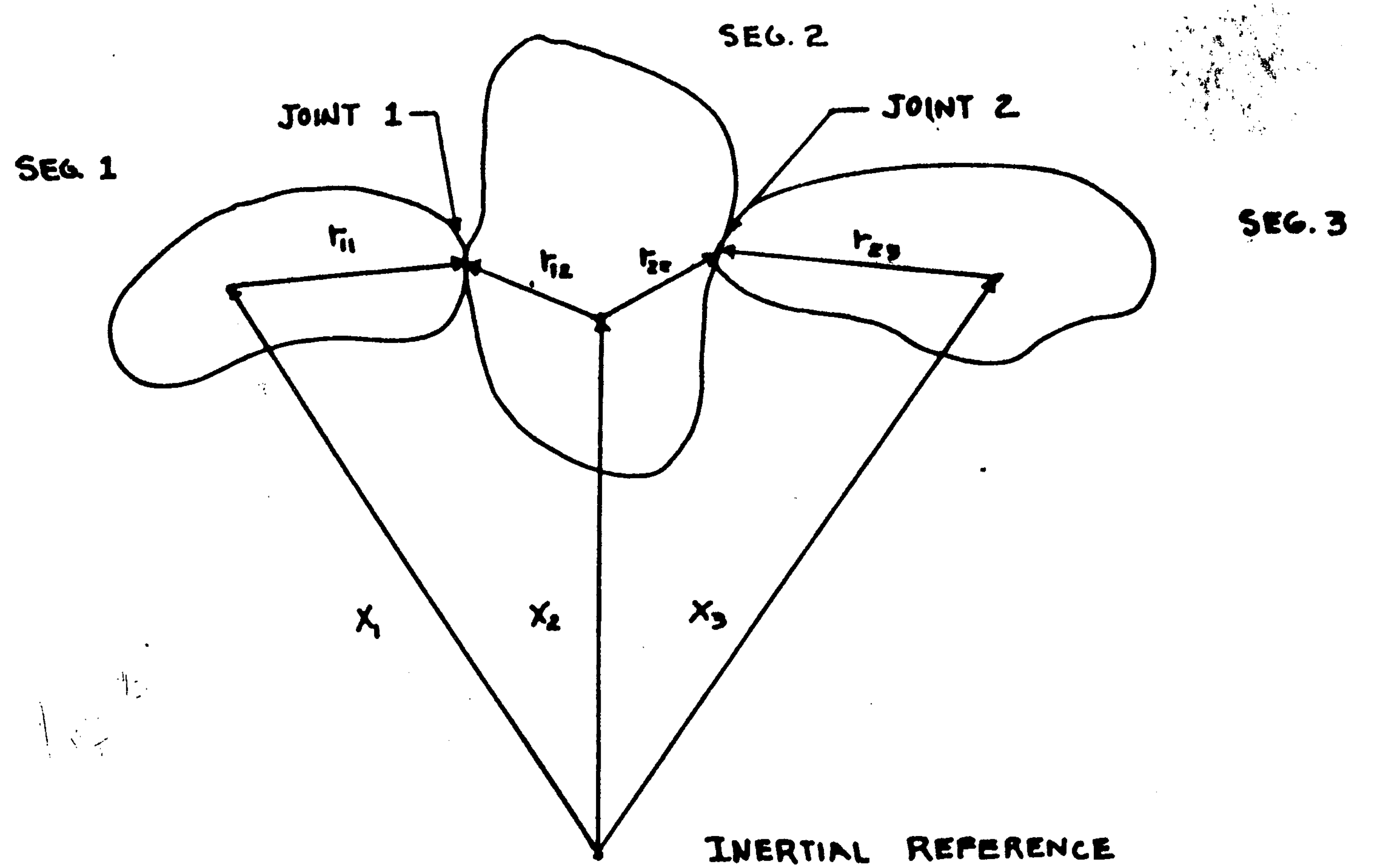
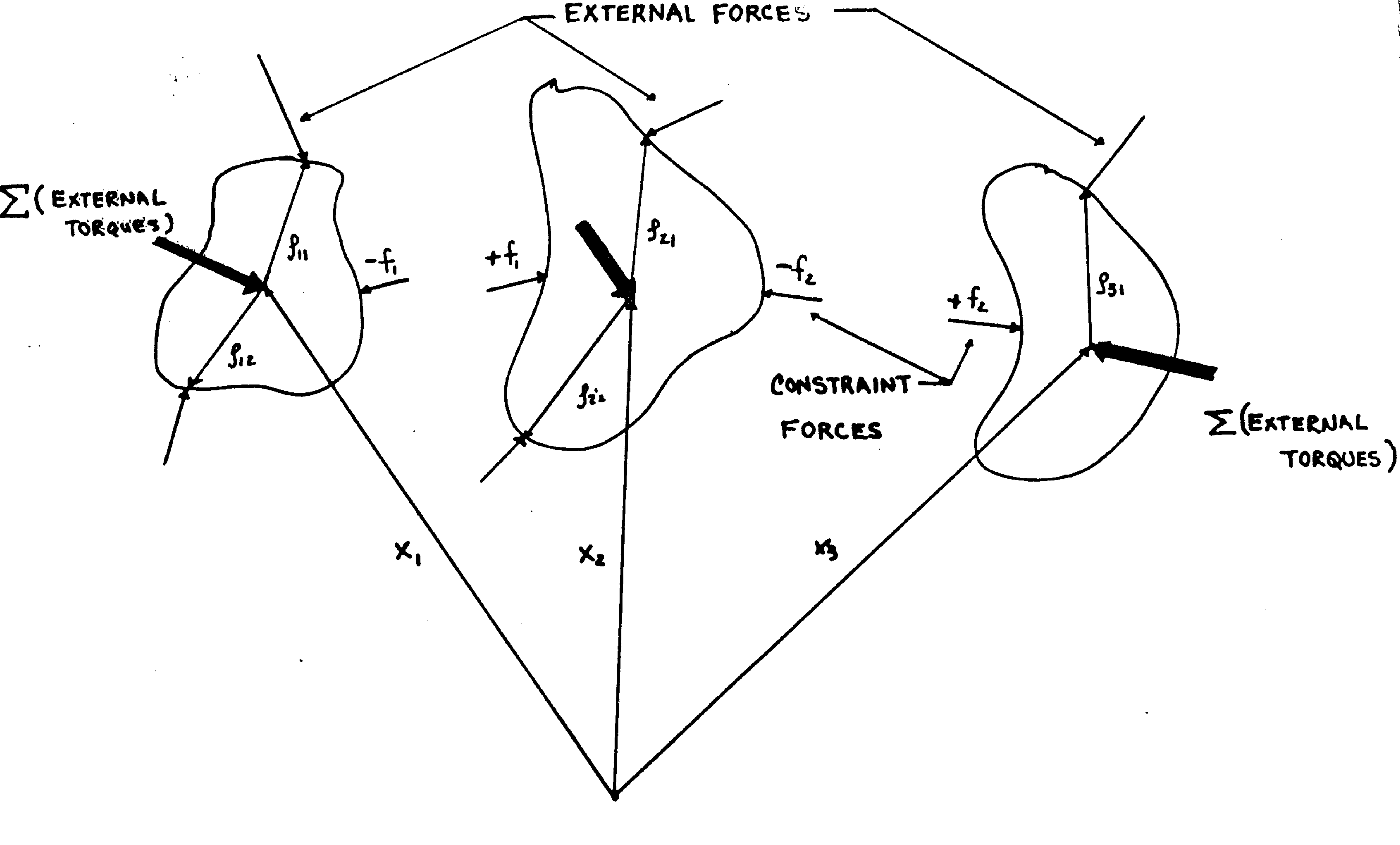
SYSTEM OF CONNECTED RIGID BODIES





FREE BODY CONFIGURATION

$$
\begin{bmatrix}
M & 0 & A_{11} & 0 & A_{13} & 0 \\
0 & \Phi & A_{21} & A_{22} & A_{23} & A_{24} \\
B_{11} & B_{12} & B_{13} & 0 & 0 & 0 \\
0 & B_{22} & 0 & B_{24} & 0 & 0 \\
B_{31} & B_{32} & 0 & 0 & B_{35} & 0 \\
0 & B_{42} & 0 & 0 & 0 & 0
\end{bmatrix}
\begin{bmatrix} \ddot{X} \\ \dot{\omega} \\ f \\ t \\ q \\ \tau \end{bmatrix}
=
\begin{array}{l}
\begin{bmatrix} U_1 \\ U_2 \\ V_1 \\ V_2 \\ V_3 \\ V_4 \end{bmatrix}
\end{array}
\begin{array}{l}
\text{FORCES} \\ \text{TORQUES} \\ \text{LINEAR JOINT} \\ \text{ANGULAR JOINT} \\ \text{SPECIAL CONSTRAINTS} \\ \text{FLEXIBLE ELEMENT}
\end{array}
$$

SYSTEM EQUATIONS

NOMENCLATURE

A_{ij}, B_{ij} = MATRICES USED IN SYSTEM EQUATIONS

f = JOINT CONSTRAINT FORCE

M = MASS MATRIX

q = SPECIAL CONSTRAINT FORCE

t = JOINT CONSTRAINT TORQUE

U_1 = EXTERNAL FORCE

U_2 = EXTERNAL TORQUE

V_j = CONSTRAINT FORCING FUNCTION

τ = FLEXIBLE ELEMENT CONSTRAINT TORQUE

Φ = INERTIA MATRIX

$\ddot{X}$ = TRANSLATIONAL ACCELERATION

$\dot{\omega}$ = ANGULAR ACCELERATION

Figure 2 SYSTEM EQUATIONS

$$
\begin{bmatrix}
M & 0 & A_{11} & 0 & A_{13} & 0 \\
0 & \Phi & A_{21} & A_{22} & A_{23} & A_{24} \\
B_{11} & B_{12} & B_{13} & 0 & 0 & 0 \\
0 & B_{22} & 0 & B_{24} & 0 & 0 \\
B_{31} & B_{32} & 0 & 0 & B_{35} & 0 \\
0 & B_{42} & 0 & 0 & 0 & 0
\end{bmatrix}
\begin{bmatrix} \ddot{X} \\ \dot{\omega} \\ f \\ t \\ q \\ \tau \end{bmatrix}
=
\begin{bmatrix} U_1 \\ U_2 \\ V_1 \\ V_2 \\ V_3 \\ V_4 \end{bmatrix}
\begin{array}{l} \text{Forces} \\ \text{Torques} \\ \text{Linear Joint} \\ \text{Angular Joint} \\ \text{Special Constraints} \\ \text{Flexible Element} \end{array}
$$

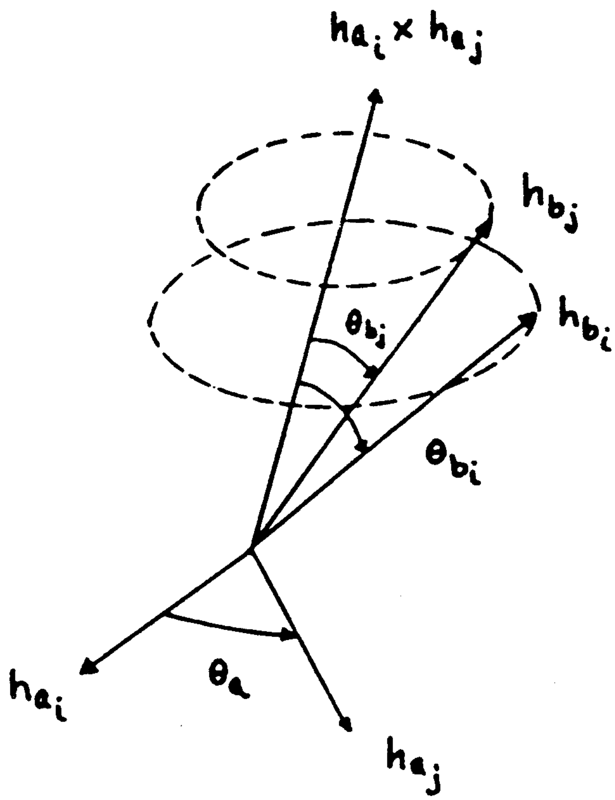
SYSTEM EQUATIONS

$$
\begin{bmatrix}
C_{11} & C_{12} & C_{13} & C_{14} \\
C_{21} & C_{22} & C_{23} & C_{24} \\
C_{31} & C_{32} & C_{33} & C_{34} \\
C_{41} & C_{42} & C_{43} & C_{44}
\end{bmatrix}
\begin{bmatrix} f \\ t \\ q \\ \tau \end{bmatrix}
=
\begin{bmatrix} V_1^* \\ V_2^* \\ V_3^* \\ V_4^* \end{bmatrix}
$$

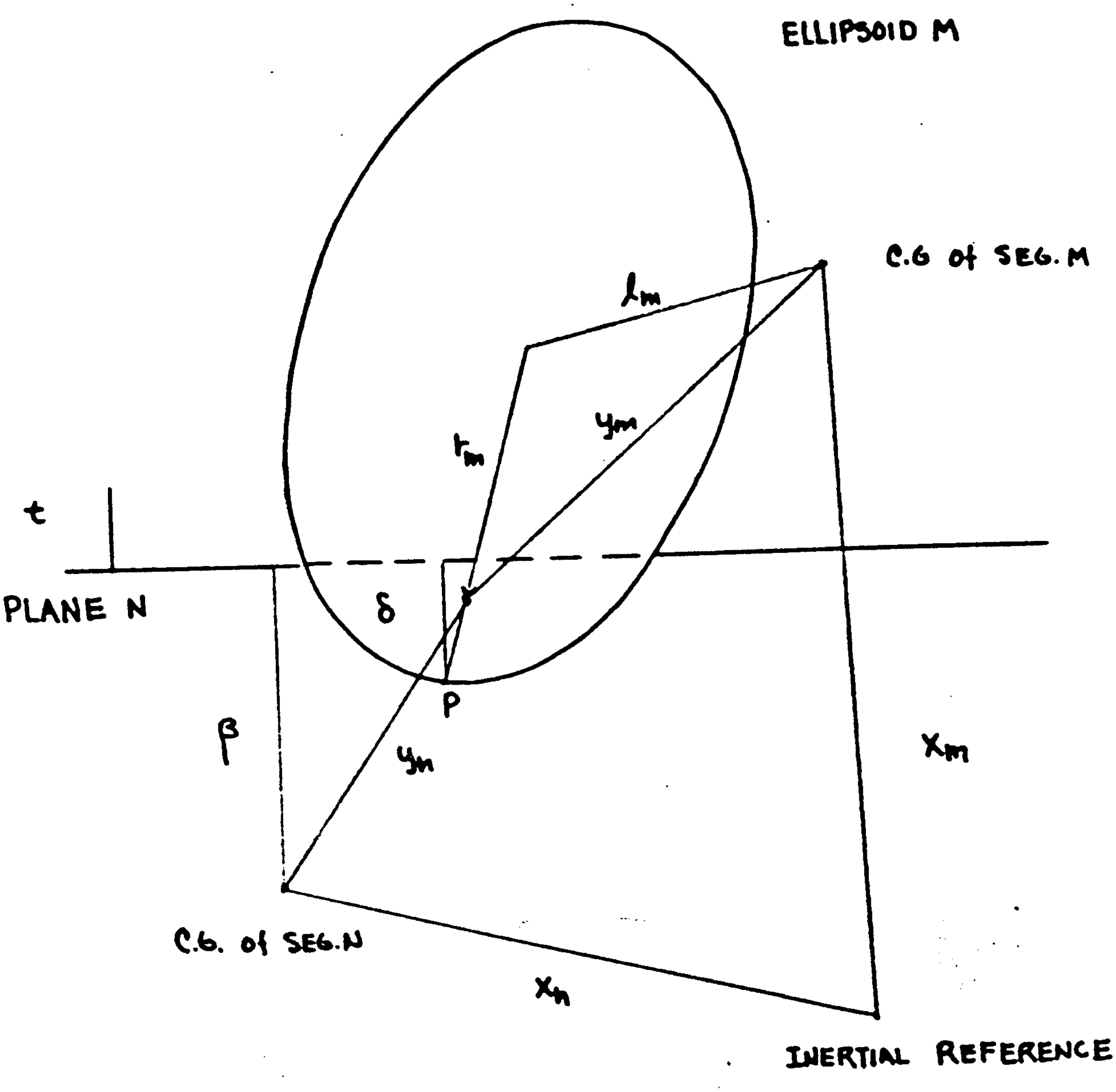
REDUCED EQUATIONS

FIGURE 2.

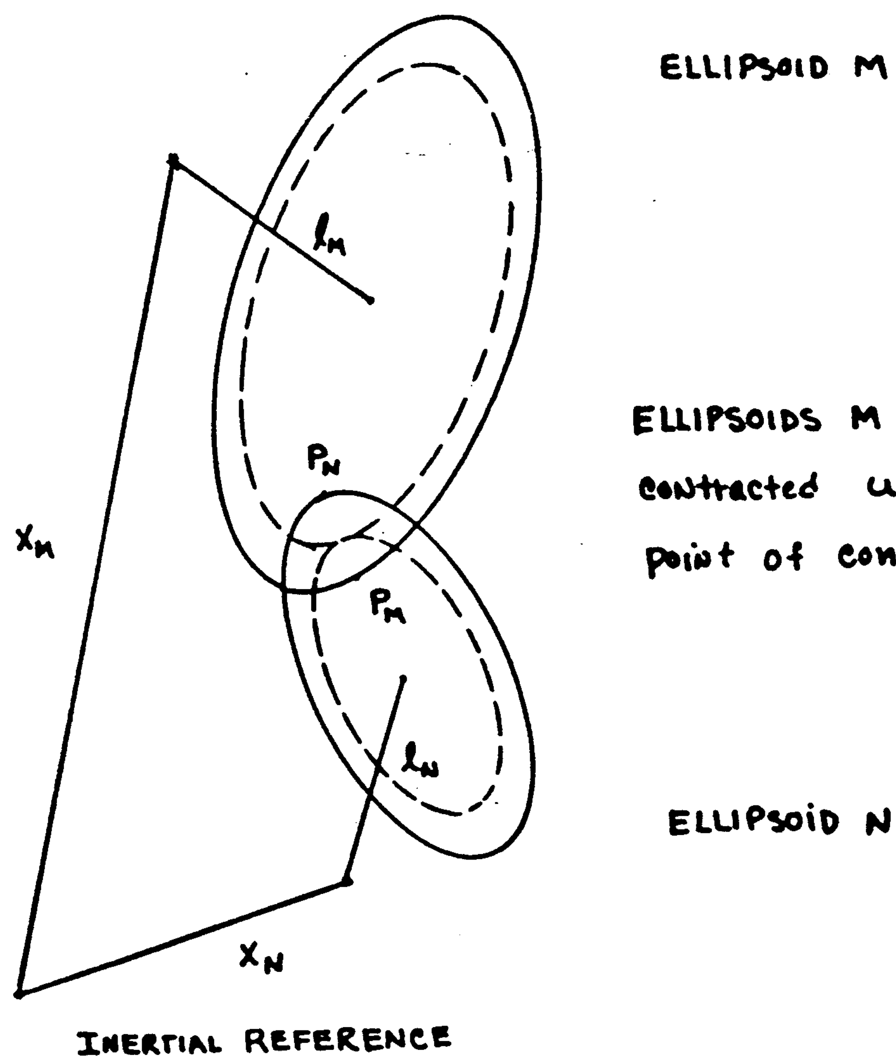
JOINT TORQUE



PLANE - ELLIPSOID CONTACT

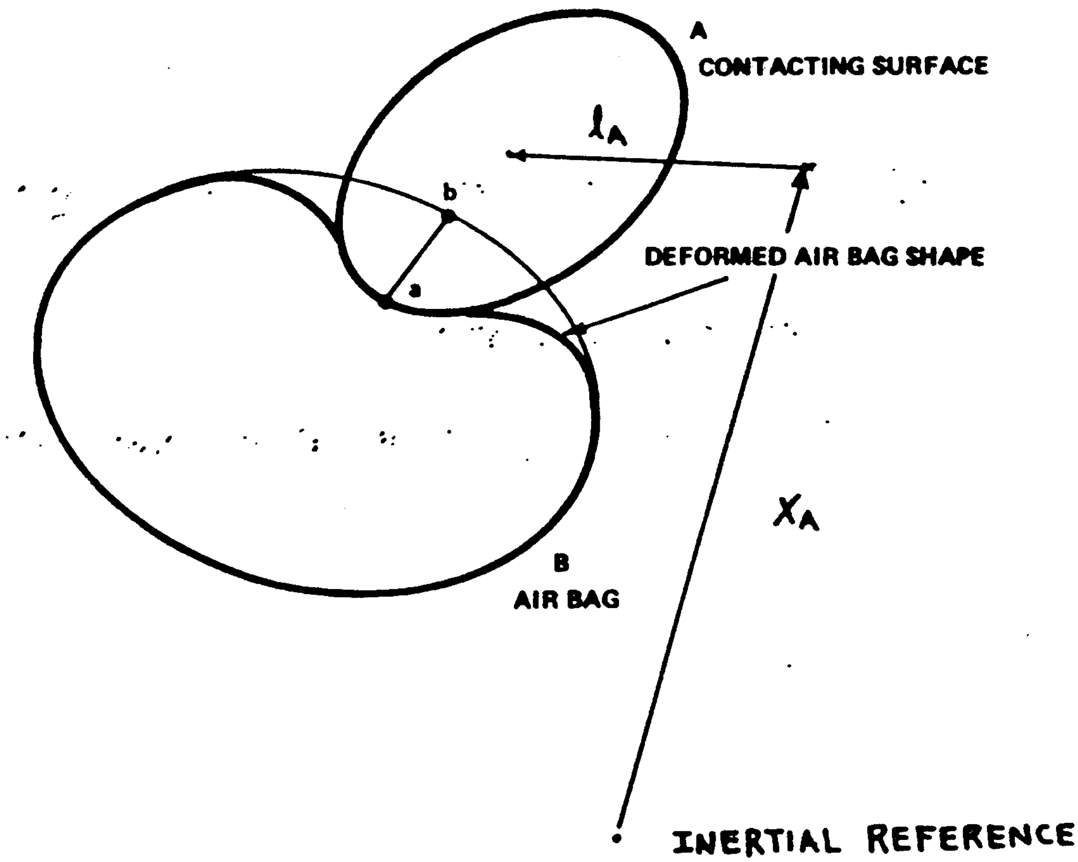


ELLIPSOID - ELLIPSOID CONTACT

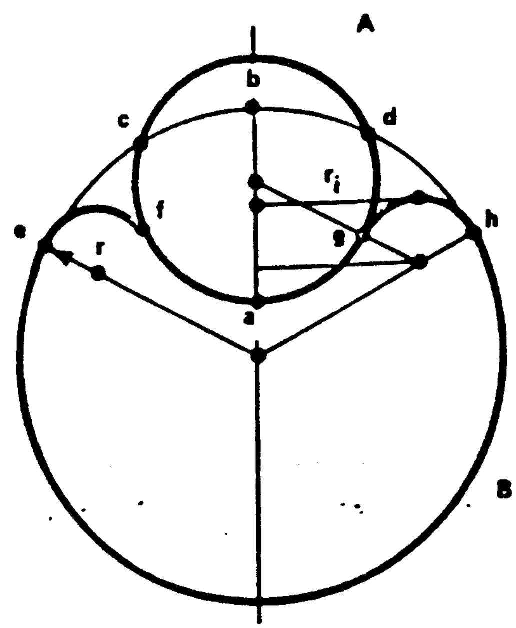


ELLIPSOIDS M and N are contracted until a single point of contact exists.

AIR BAG CONTACT



VOLUME OF CONTACT



ELLIPSES IN EACH OF THE PERPENDICULAR PLANES ARE REPLACED BY CIRCLES.

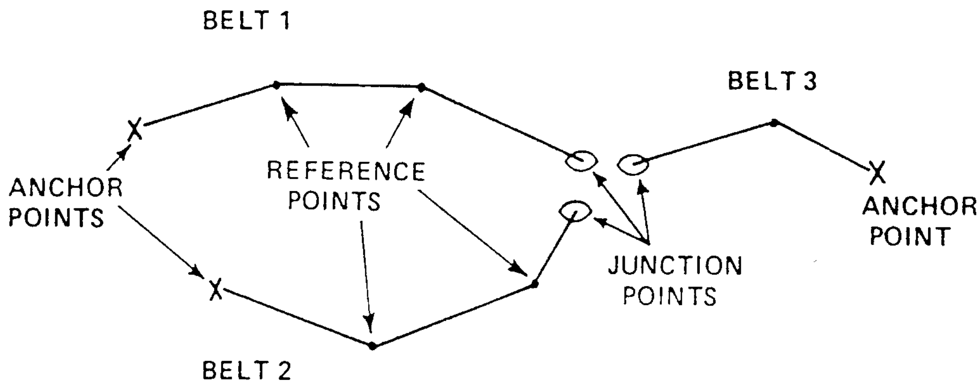


Figure 3 BELT HARNESS MODEL

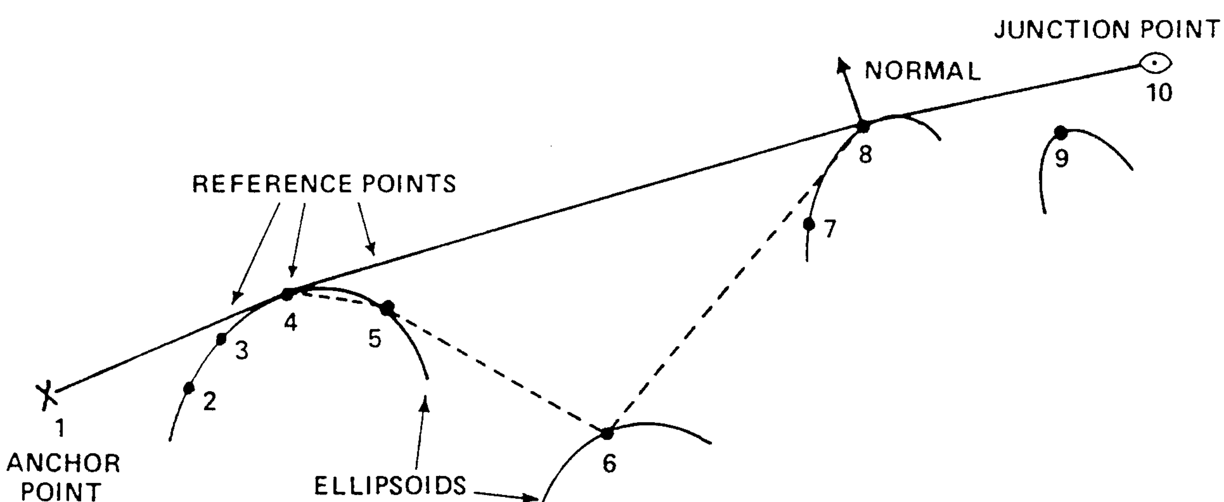


Figure 4 REFERENCE POINT SELECTION

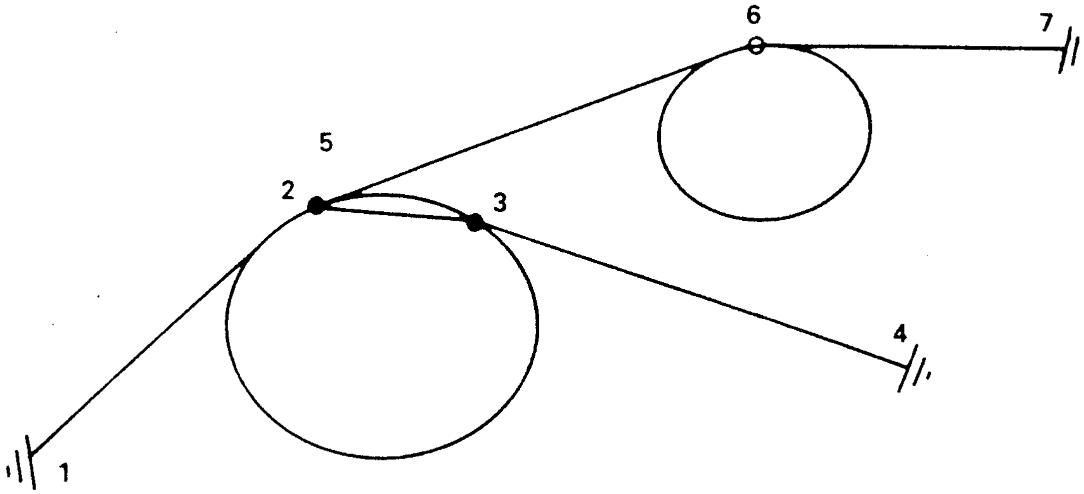


Figure 6 POINTS OF A SAMPLE BELT SYSTEM

$$
\begin{vmatrix}
 & & I & & & -I & & \\
 & X & X & & & & & \\
I & X & X & X & & & & \\
 & & X & X & X & & & \\
 & & & X & X & & & \\
-I & & & & & X & X & \\
 & & & & & X & X & X \\
 & & & & & & X & X
\end{vmatrix}
\begin{Vmatrix}
\delta\lambda_1 \\ \delta p_1 \\ \delta p_2 \\ \delta p_3 \\ \delta p_4 \\ \delta p_5 \\ \delta p_6 \\ \delta p_7
\end{Vmatrix}
=
\begin{vmatrix}
0 \\ y_1 \\ y_2 \\ y_3 \\ y_4 \\ y_5 \\ y_6 \\ y_7
\end{vmatrix}
$$

I 3 x 3 IDENTITY MATRIX

X NON ZERO 3 x 3 ENTRY

$\delta\lambda_1$ LAGRANGE MULTIPLER

δp_k PERTURBATIONS

y_k RIGHT HAND SIDE (ZERO WHEN CONVERGED)

Figure 7 MATRIX FORM OF CONSTRAINT EQUATIONS

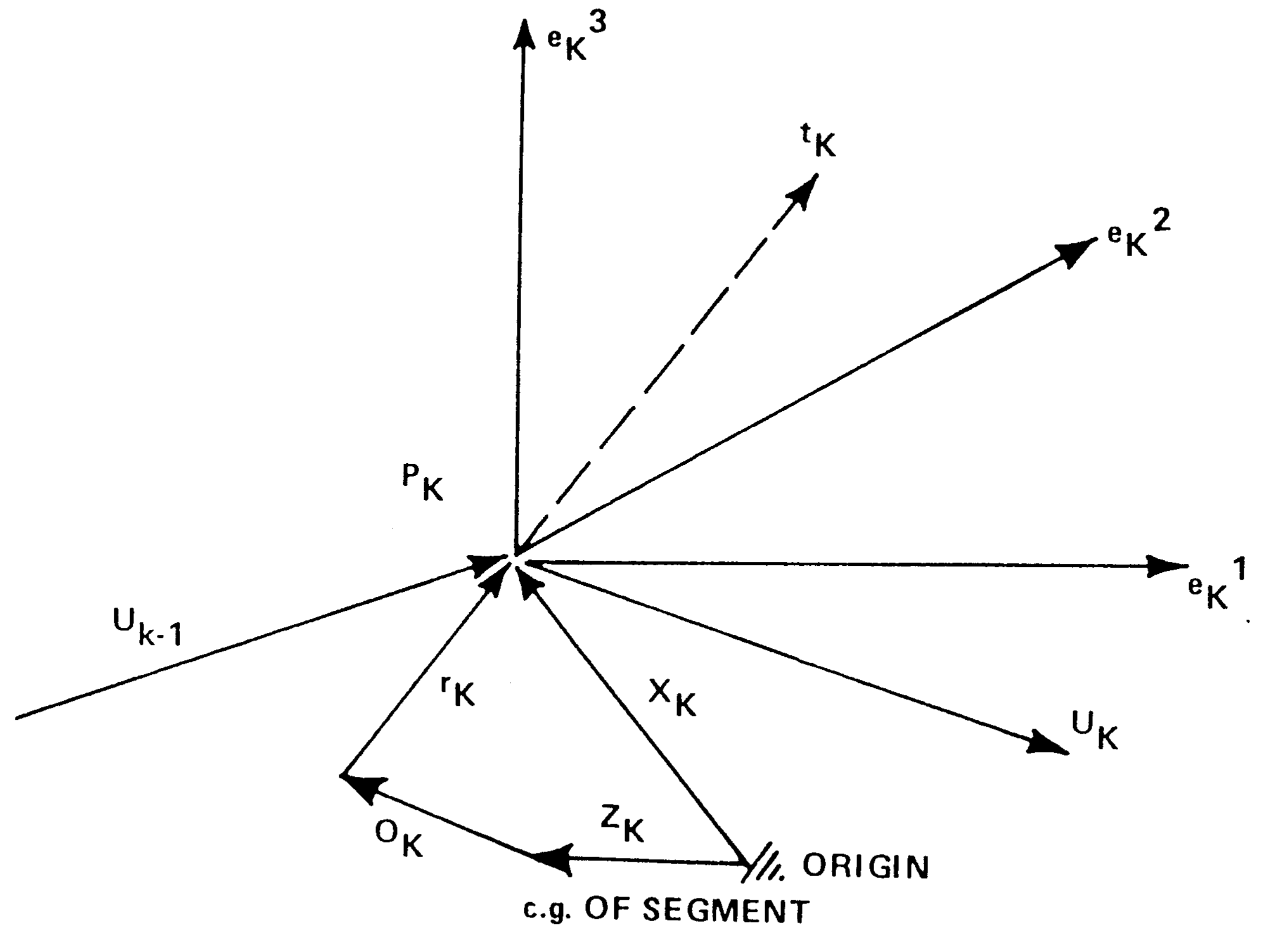


Figure 5 GEOMETRY OF A POINT FOR ADVANCED HARNESS-BELT SYSTEM

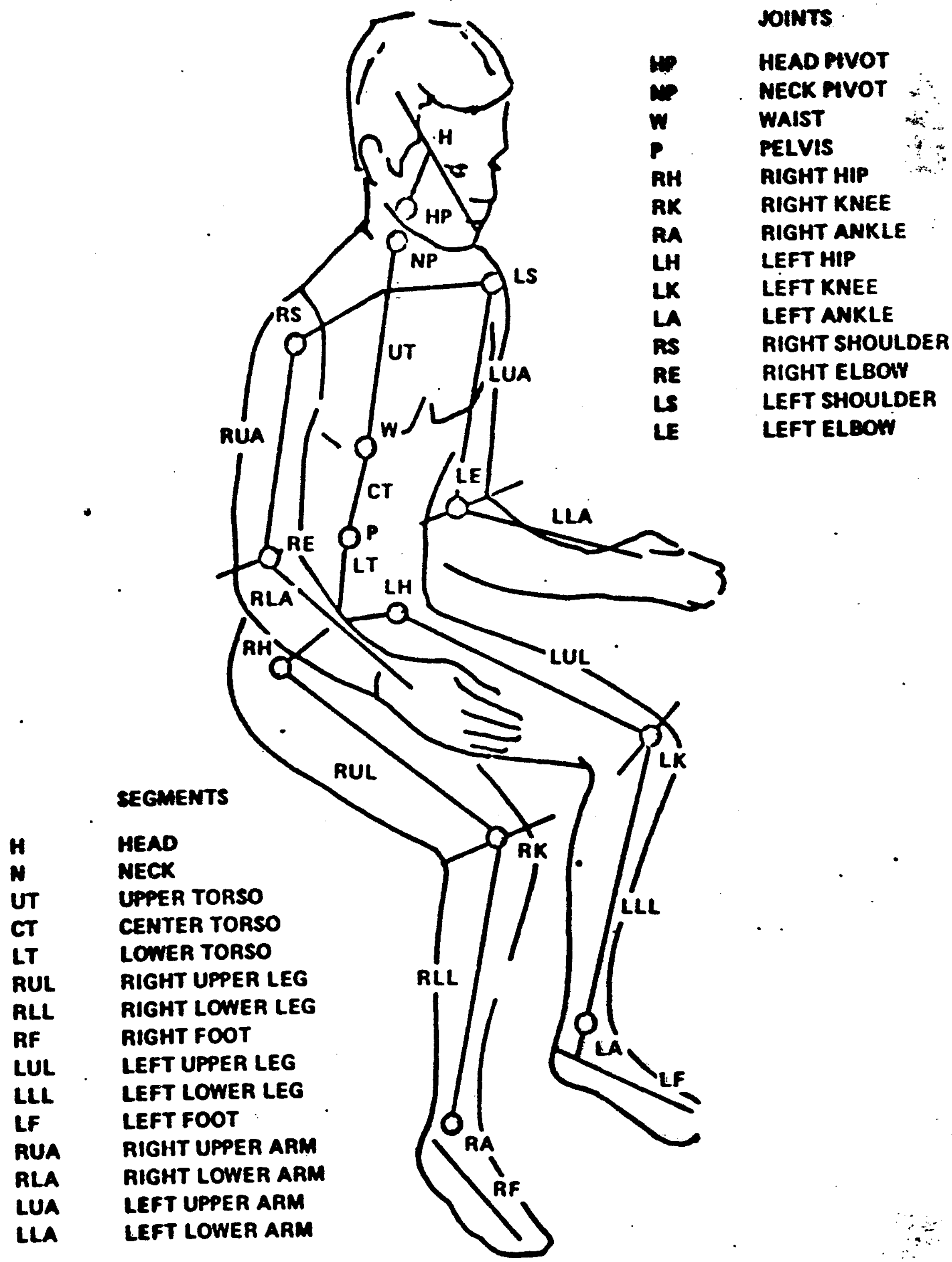
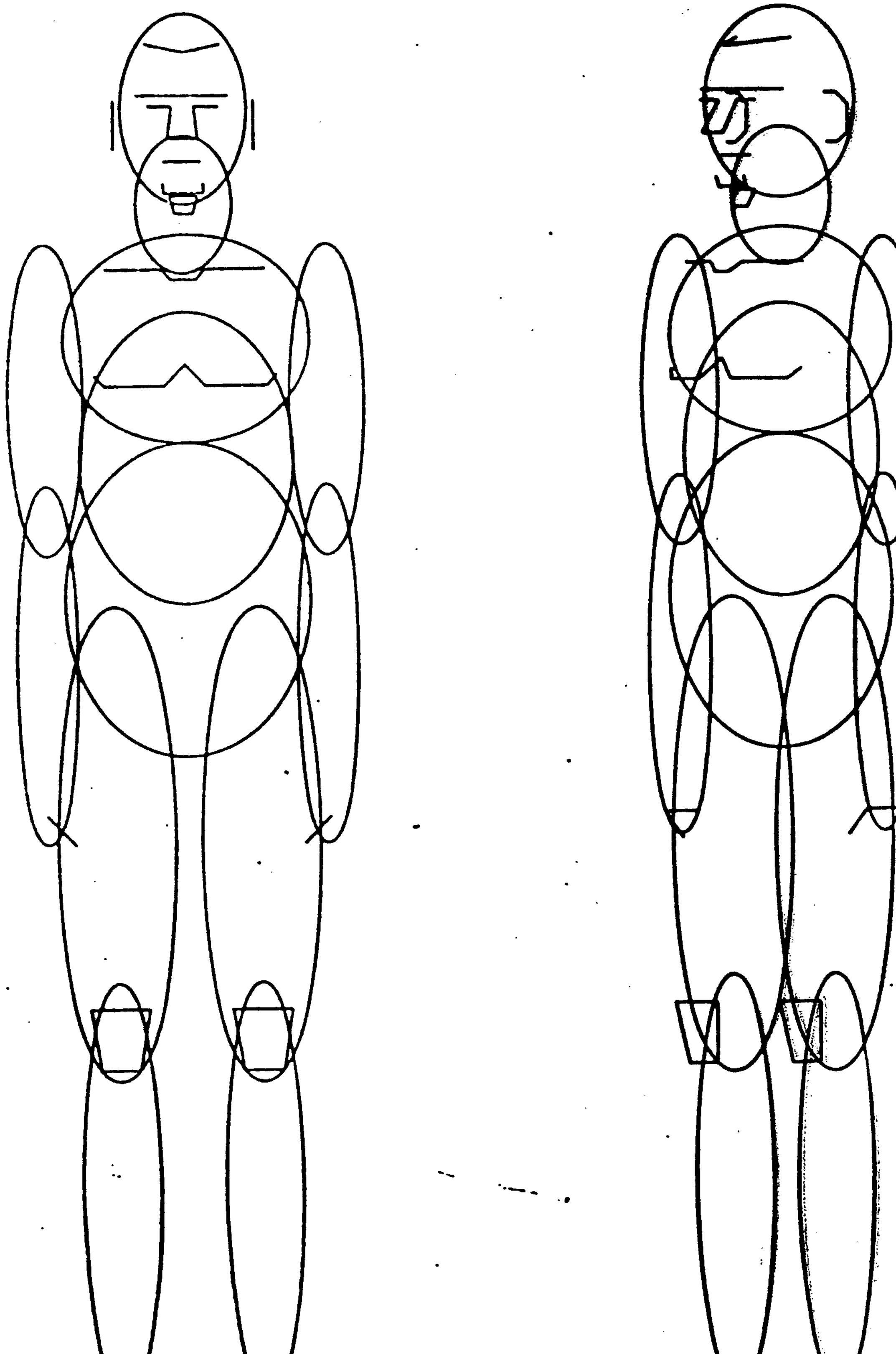


Figure 1 FIFTEEN SEGMENT MAN-MODEL

CONTACT MODEL



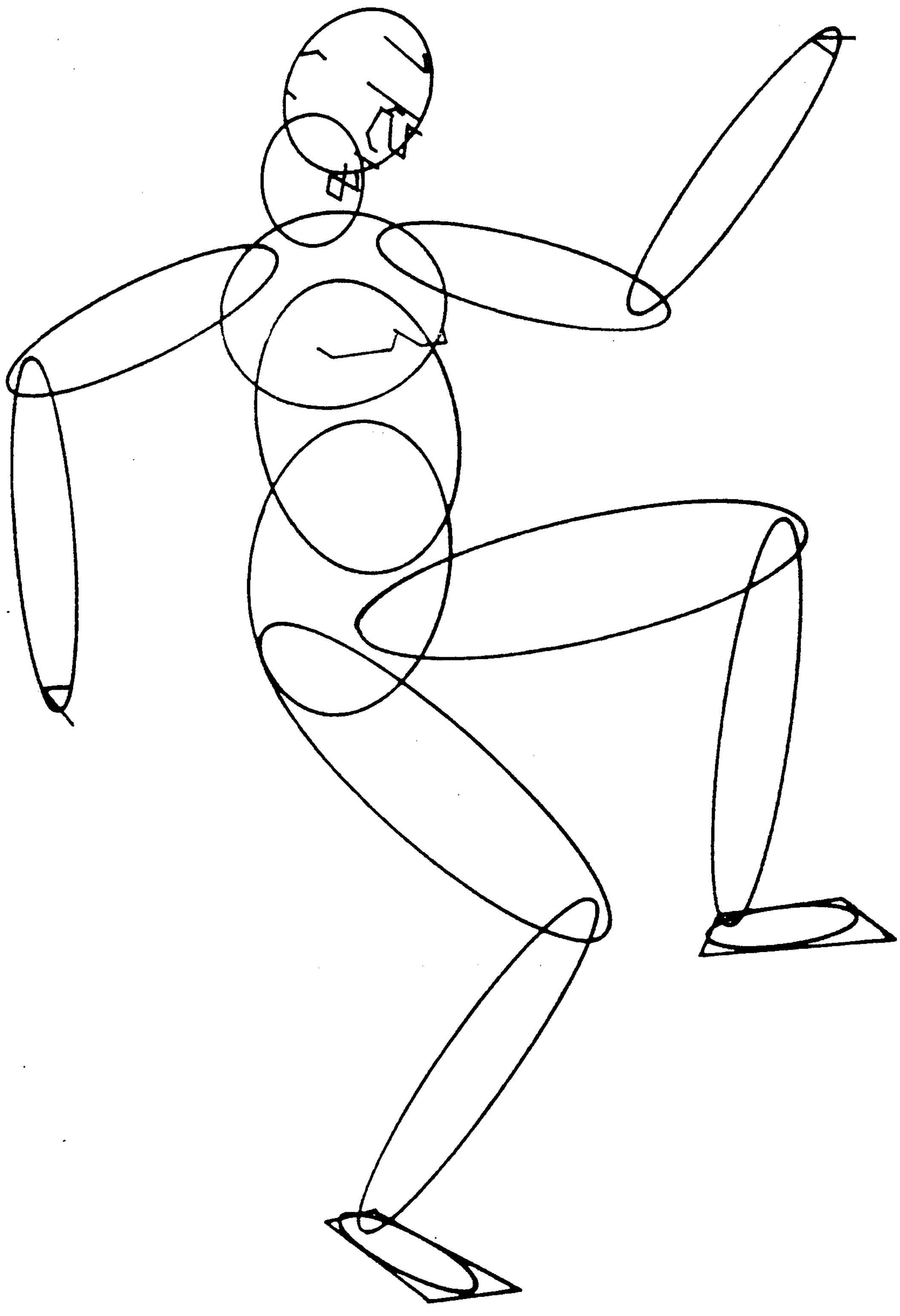
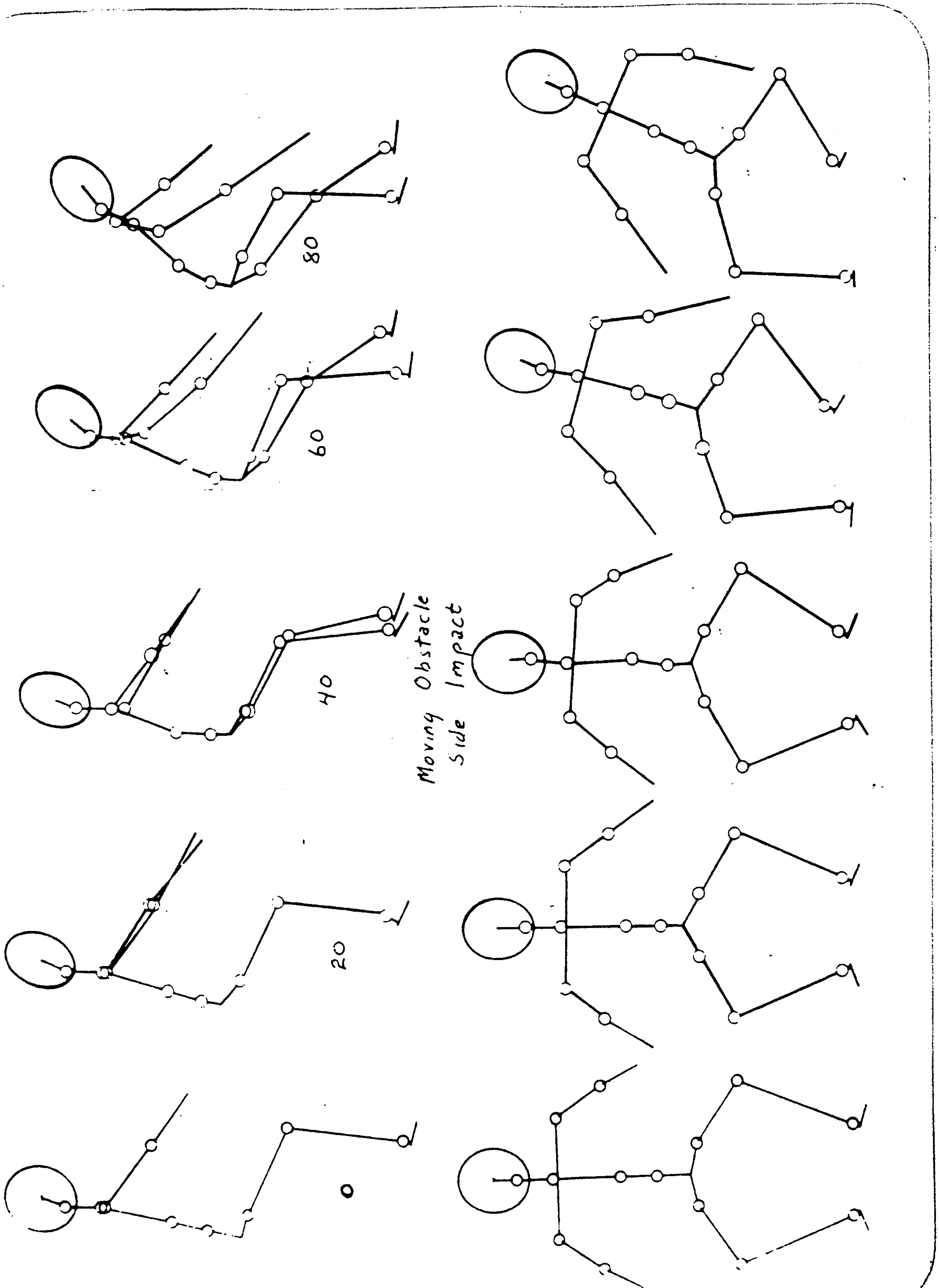
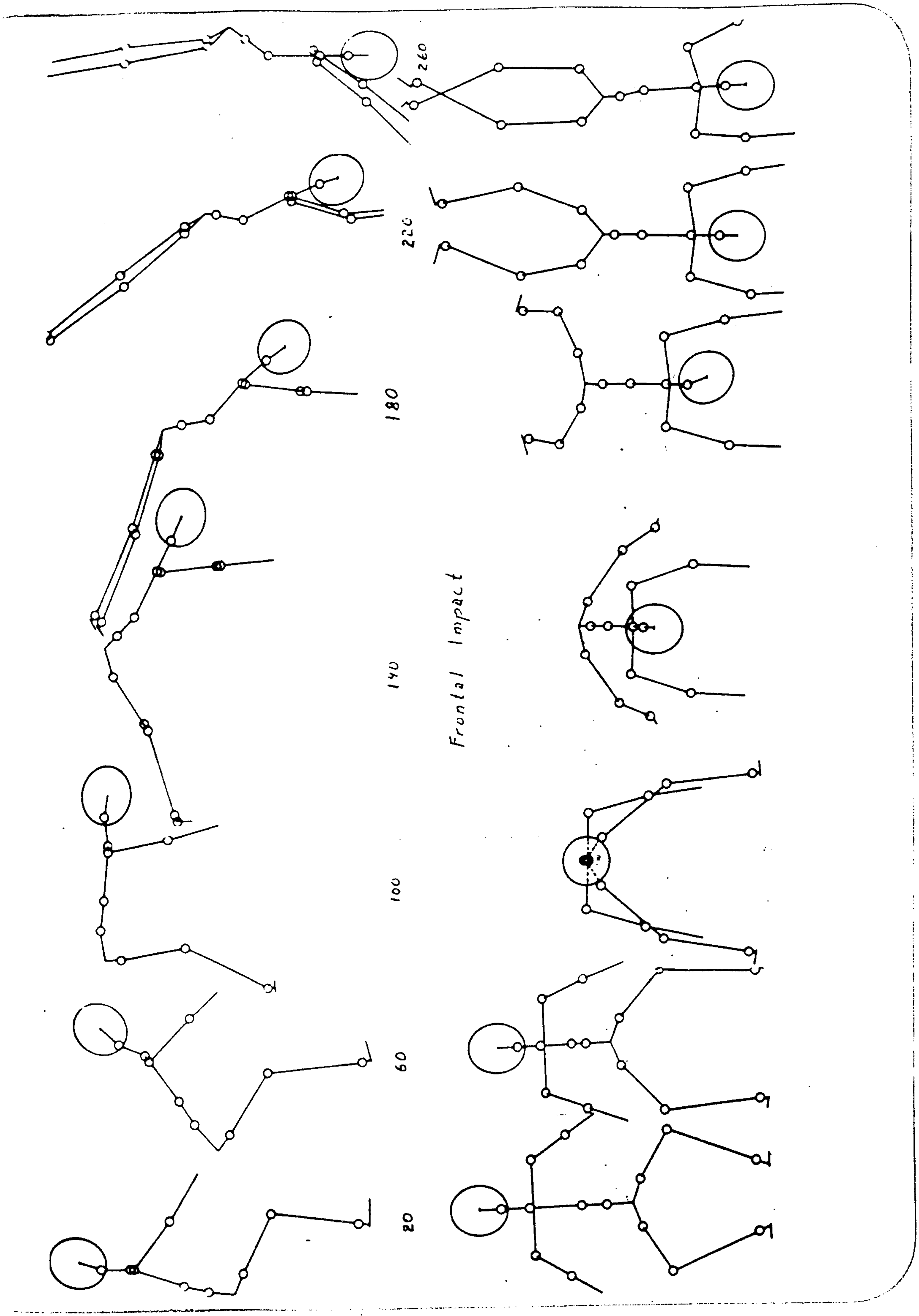


Figure 1 A TYPICAL 15 SEGMENT BODY MODEL


0
20
40
60
80
Moving Obstacle
Side Impact


Frontal Impact
20
60
100
140
180
220
260

PROGRAM APPLICATIONS

- STANDARD 15-SEGMENT OCCUPANT
- MULTIPLE OCCUPANTS - INTERACTING WITH EACH OTHER, VEHICLE OR GROUND
- AIRPLANE OCCUPANT
- MOTORCYCLE OR BICYCLE OPERATOR
- PASSENGER DYNAMICS IN CONTROLLED RAPID TRANSIT VEHICLES.
- GENERAL 3-D MOTION OF SETS OF INTERCONNECTED OR DISJOINT RIGID BODIES

Presentation of

David J. Biss
Automotive Safety Analysis Corporation

at

The 1995 ATB Model User's Colloquium

June 13, 1995

USE OF ATB IN A REAR IMPACT RECONSTRUCTION

Abstract

An interesting field case study was undertaken involving a 180 deg. rear impact in which the driver's seat back did not appreciably deform or collapse rearward raising an issue regarding the efficacy of a head restraint adjusted in the full down position. A chosen component of the case study was the use of the ATB model to analyze occupant kinematics and dynamics with alternative height head restraints. A methodology will be presented to the ATB User's Colloquium showing the development of the case occupant anthropometry and the rendering of that dimensioned occupant with a GEBOD2 generated surrogate for ATB work. This ATB study is still in progress and questions will be presented to, and answers solicited from, the very knowledgeable body of attendees at the ATB User's Colloquium to elicit some insight regarding: 1) Assisting the diagnosis of some ongoing specific user problems, and in the further successful application of ATB to this rear impact accident mode study; and, 2) Presenting to the ATB User's Colloquium a user's case study demonstrating the need for an Internet or other on-line forum so that the considerable collective insights gained by the very diverse group of users during their many varied applications of the model would be available to others with similarly recurring user problems.

Seat Structure Modeling
and
Fixing a Bug in the ATB Harness-Belt Unloading Algorithm

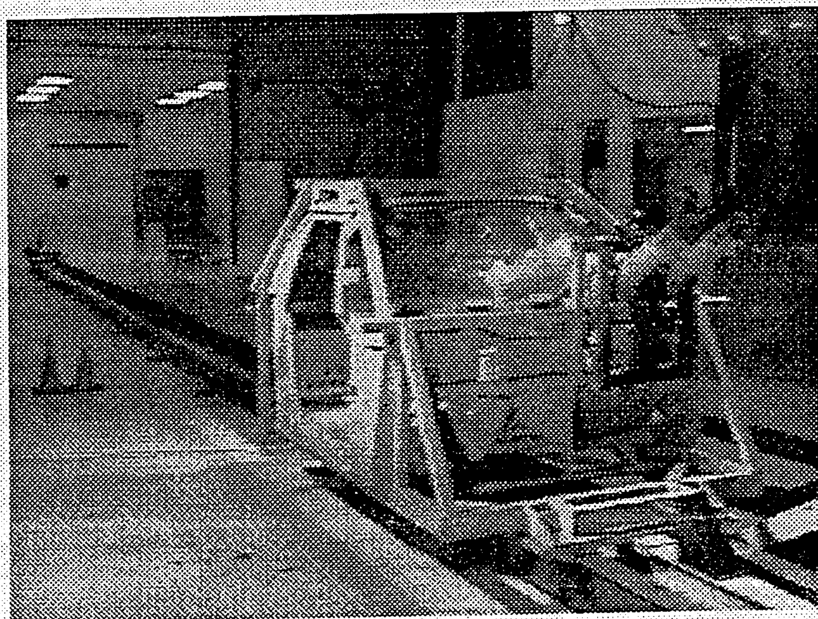
Ed Sieveka

University of Virginia
Automobile Safety Laboratory

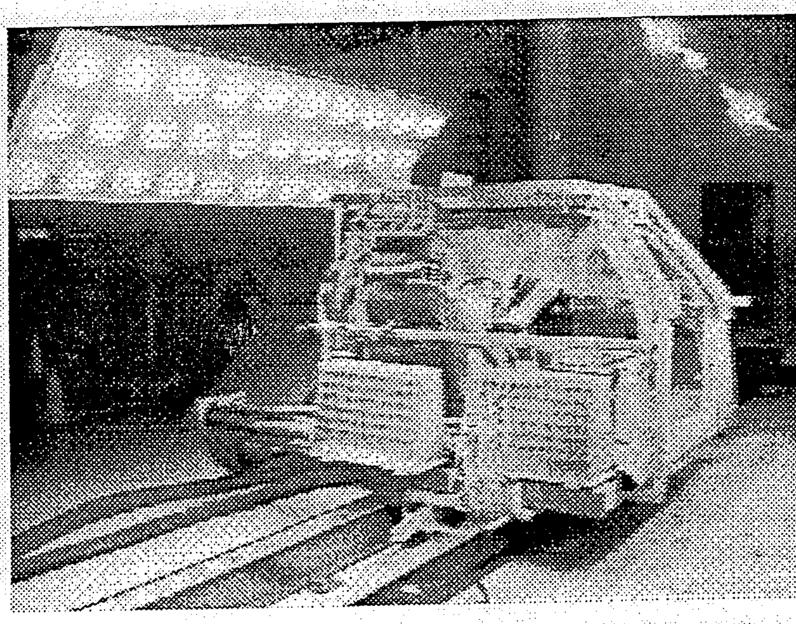
ATB Simulation and Automobile Safety Research at the University of Virginia Automobile Safety Laboratory

- UVA has been working with ATB for about 6 years
- ASL experiments provide a ready source of ATB validation data
- ATB is used in conjunction with research at the ASL for experiment design, analysis of results, and parametric studies

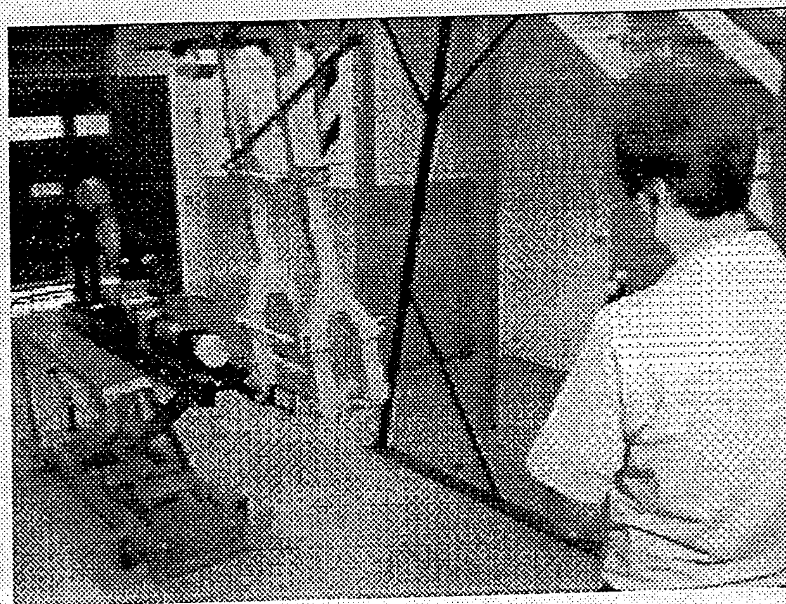
The UVA Deceleration Sled: Front View



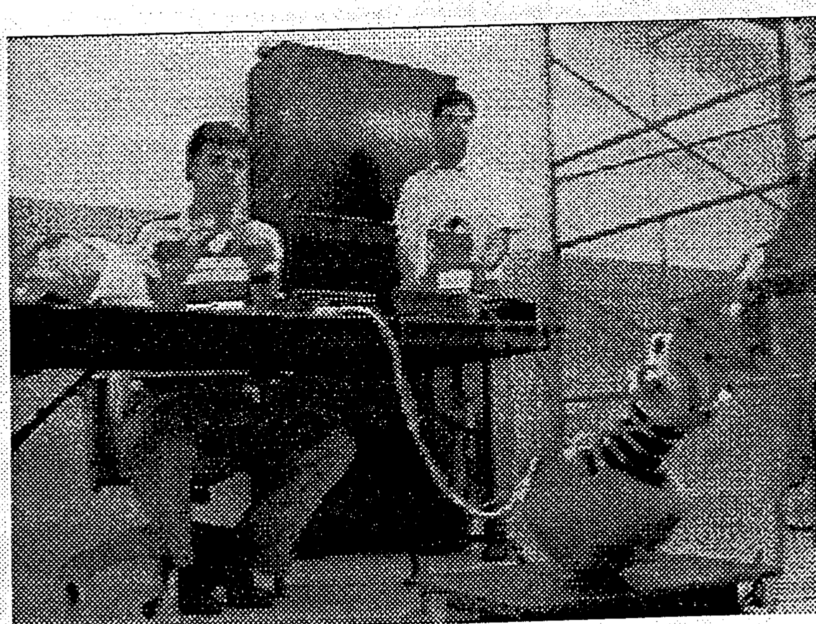
The UVA Deceleration Sled: Rear View



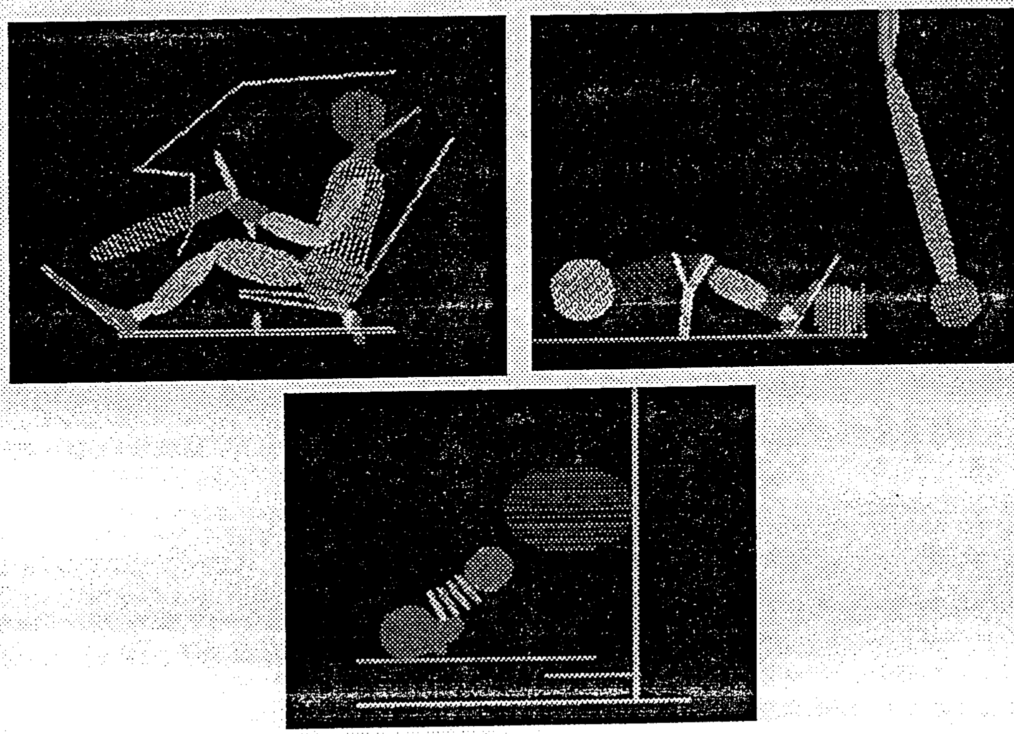
Toepan Intrusion Using the UVA Compound Pendulum



The UVA Head-drop Device

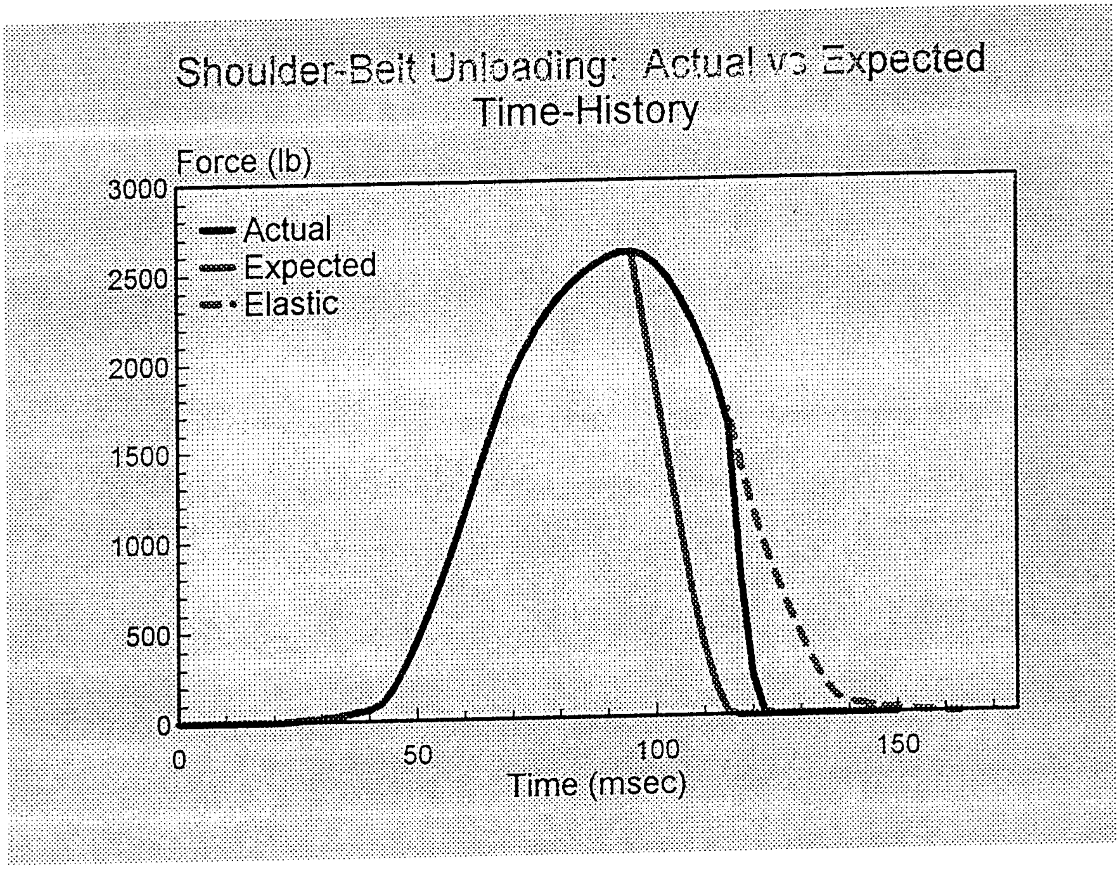


ATB Simulations for the UVA-ASL

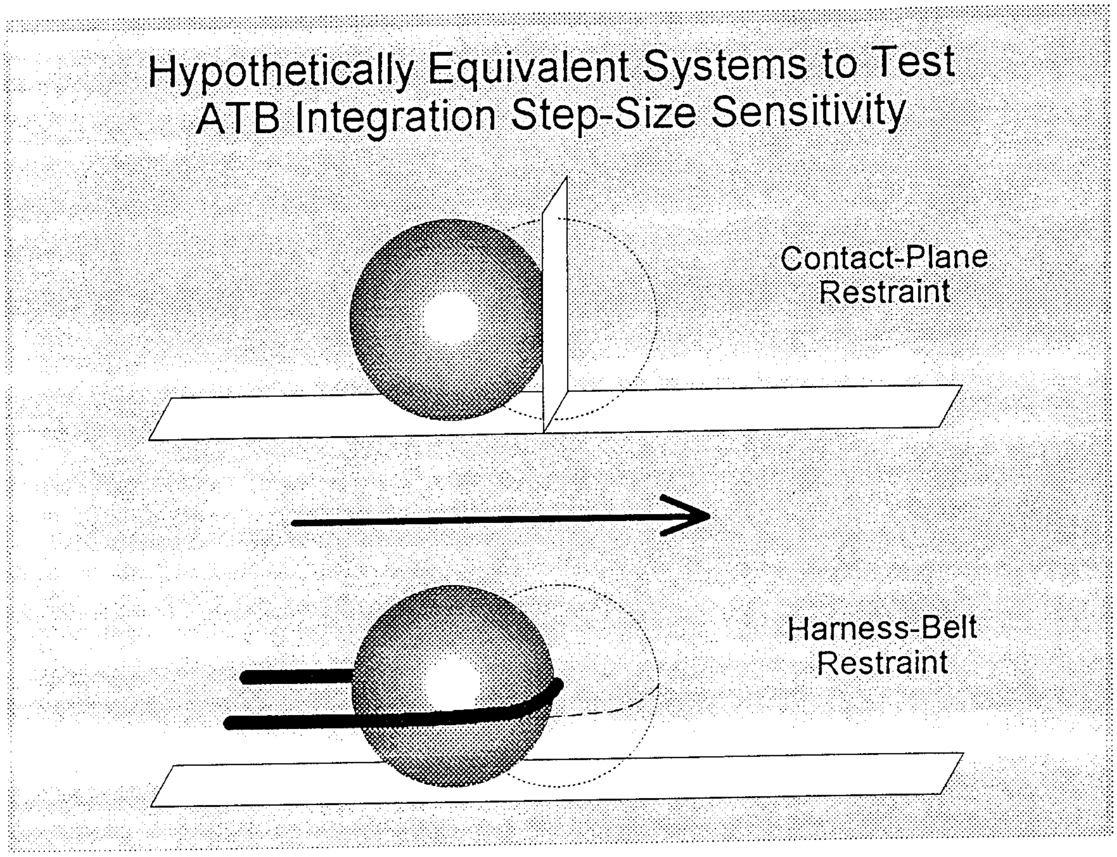


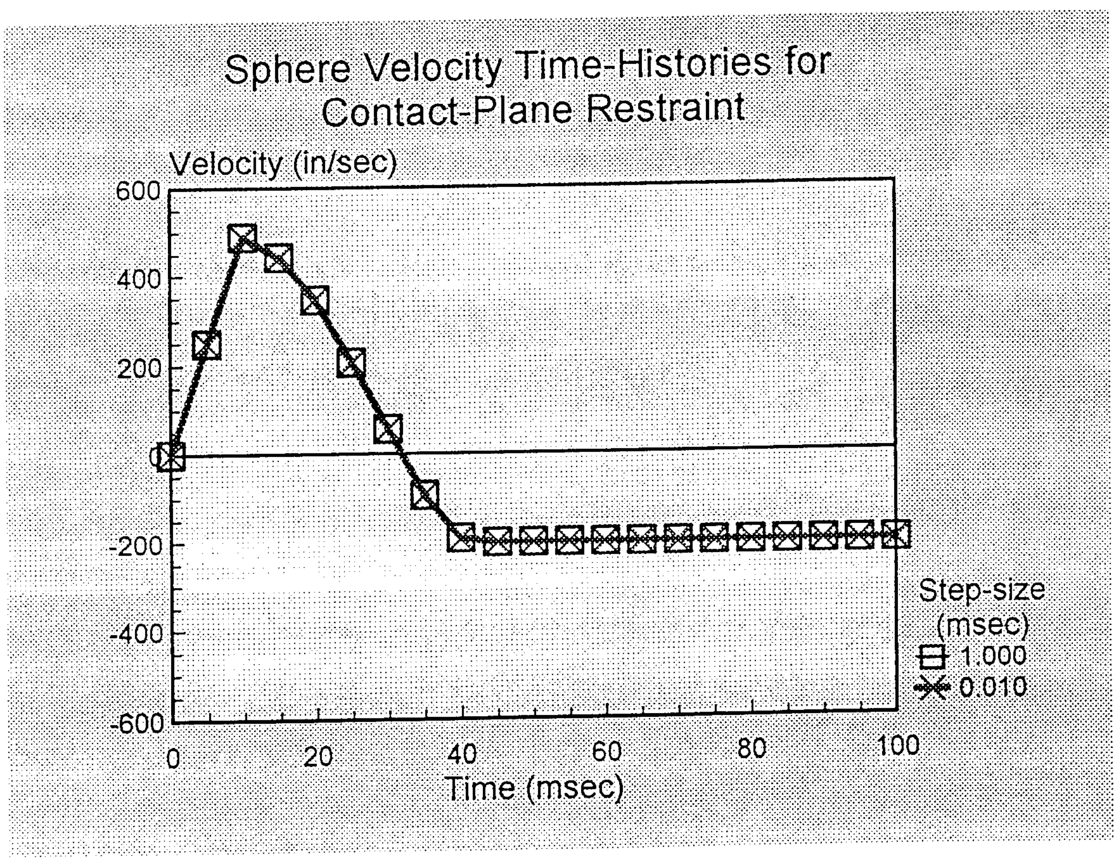
Part I: An Unloading Problem in the ATB Harness Belt Routine

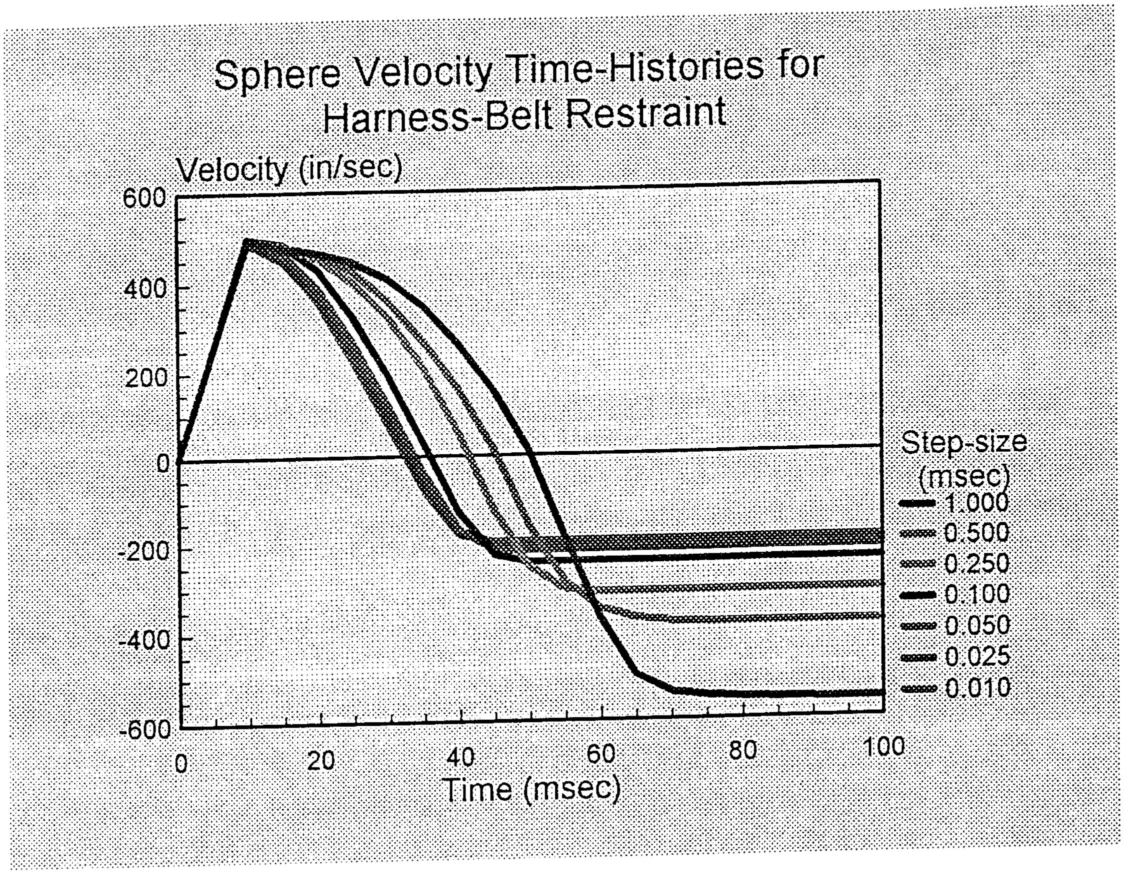
- Experienced excessive occupant rebound in simulation of a frontal impact sled test
- Reduced harness-belt elasticity via the R and G factors
- No significant improvement in occupant kinematics occurred
- Shoulder-belt load time-histories showed absence of expected inelasticity



Is the unloading problem related to the integration step-size?

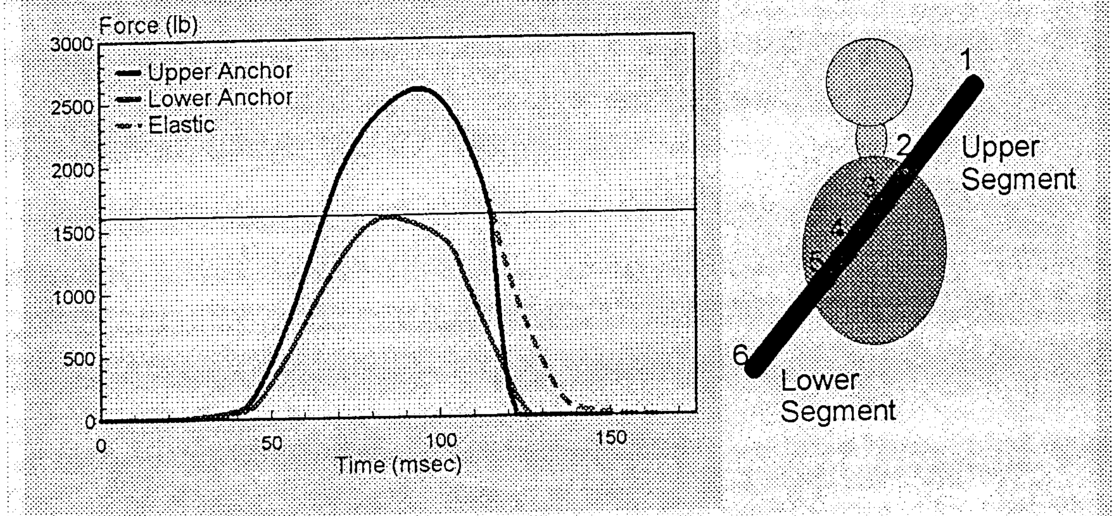

Hypothetically Equivalent Systems to Test
ATB Integration Step-Size Sensitivity
Contact-Plane
Restraint
Harness-Belt
Restraint


Sphere Velocity Time-Histories for
Contact-Plane Restraint
Velocity (in/sec)
600
400
200
0
-200
-400
-600
0
20
40
60
80
100
Time (msec)
Step-size
(msec)
1.000
0.010



However, reducing the step-size in the occupant simulation had no effect on the results.

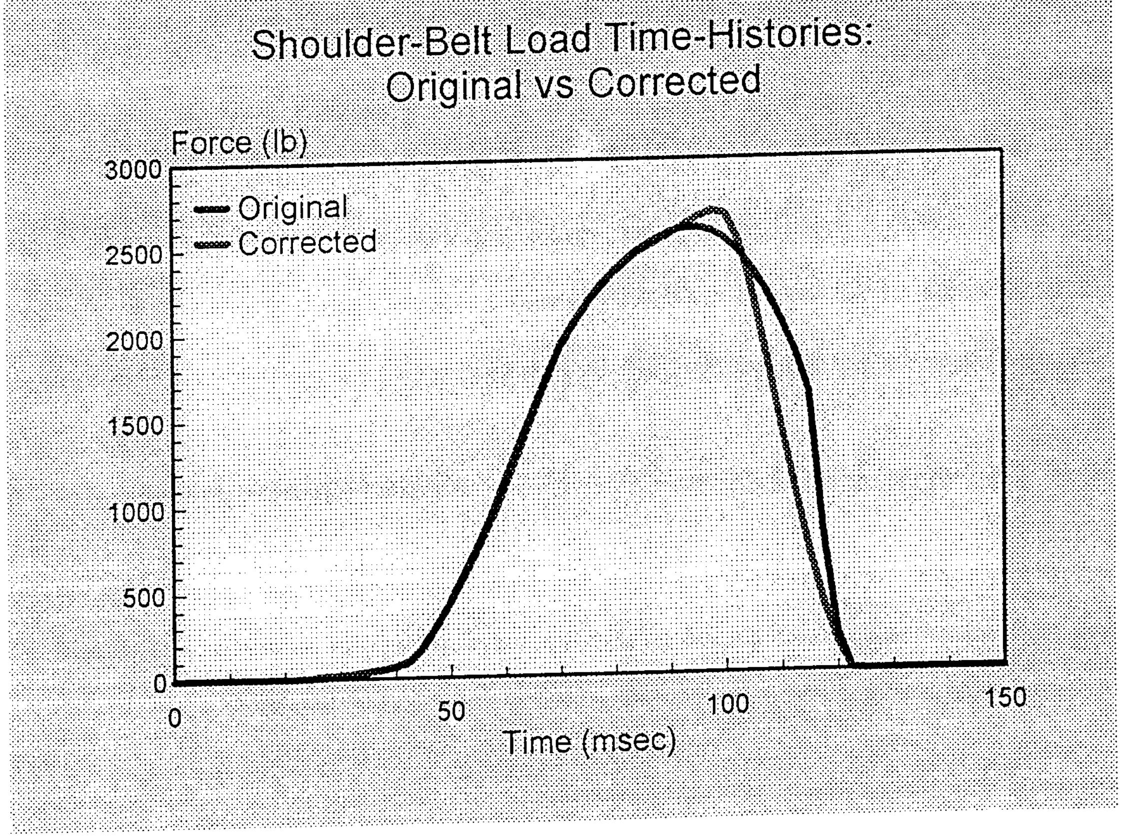
Further examination of the belt load time-histories revealed that inelastic unloading at the upper shoulder belt segment did not begin until the load fell below the maximum load achieved by the lowest segment.



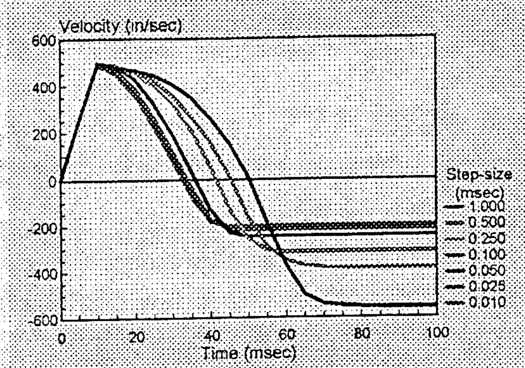
The unloading problem is caused primarily by a failure of ATB to store load history information for all but the last segment

The problem is fixed by ...

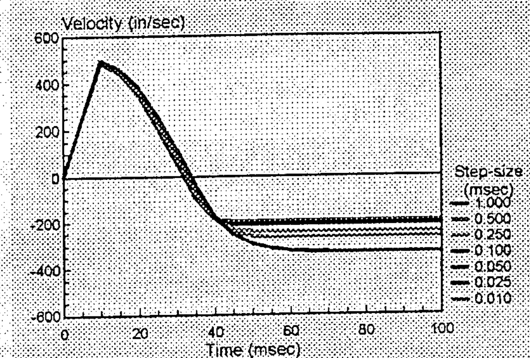
- Increasing the dimensions of array NTHRNS from (20) to (20,25) to provide storage for each belt point
- Store load history information for each belt point in the TAB and NTAB arrays
- Determine unloading for each belt point separately



Sphere Velocity Time-Histories: **Original**



There is still a noticeable sensitivity to integration step-size in the harness-belt algorithm, but the magnitude of the effect is considerably reduced

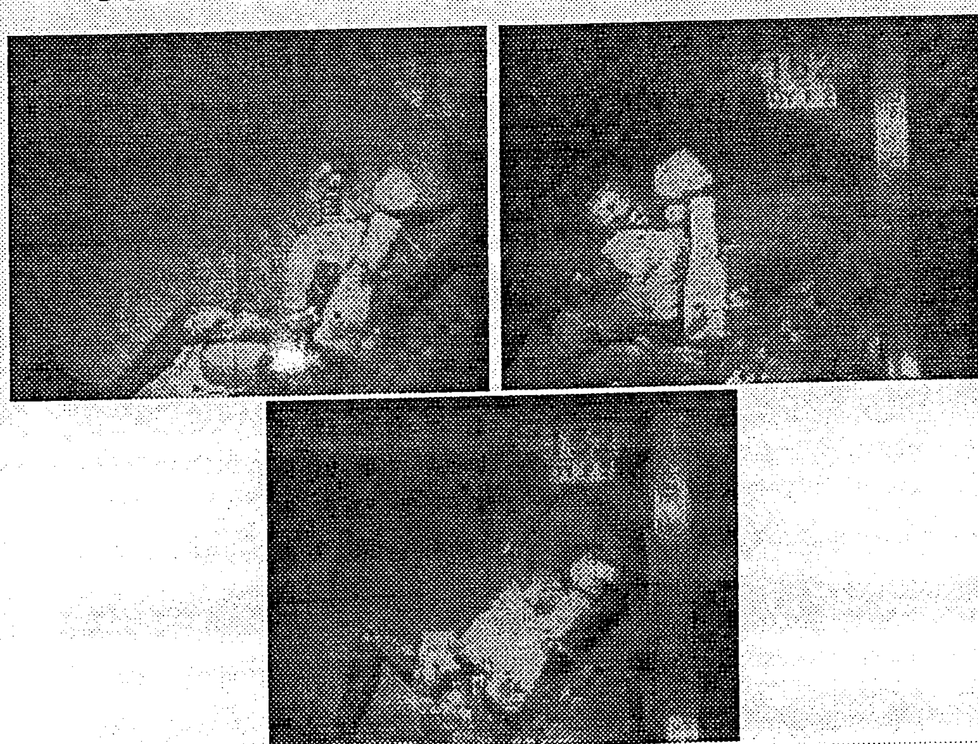


Sphere Velocity Time-Histories: **Corrected**

Part II: Using ATB to Model the Structure of a Passenger Car Seat

- Performed in support of an NHTSA project to develop a MADYMO seat model
- Useful for studying seat-back response in rear impacts or in frontal impacts with integrated seat belts
- Allows loading information to be obtained with much greater efficiency than with a F.E. model

Seat Test on UVA Sled: Frontal, 30 MPH

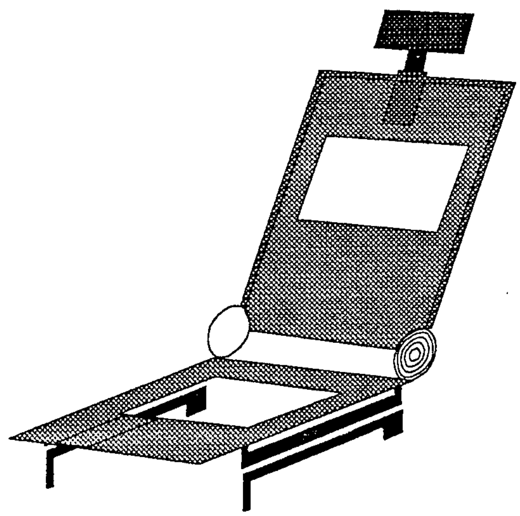


11 MPH
Rear Impact
Seat Test on
UVA Sled

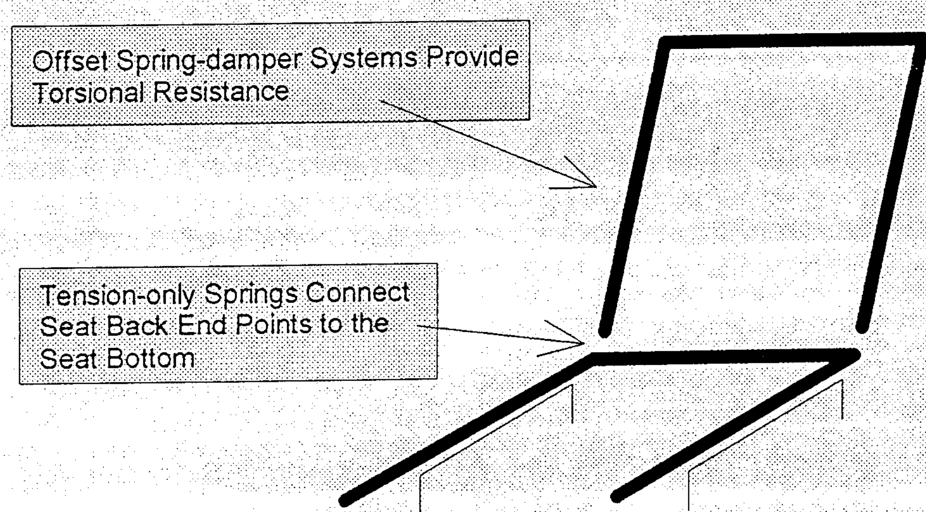
Modeling Considerations:

- Seats are not symmetric side-to-side nor are the applied loads
- Major seat load paths and degrees of freedom must be simulated
- The tree-structured nature of MADYMO and ATB must be worked around

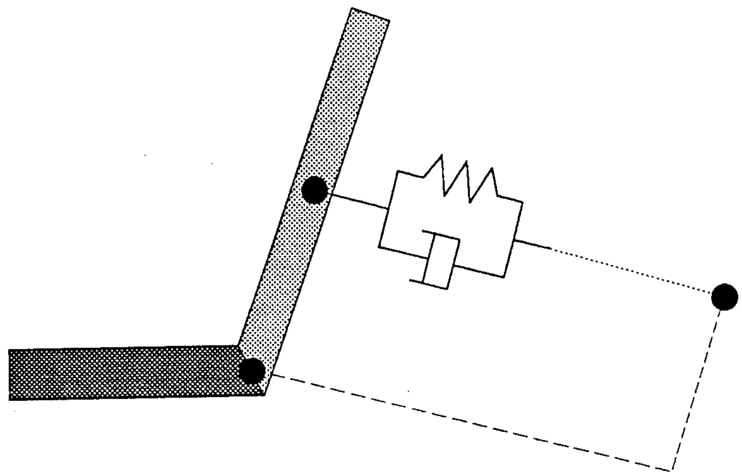
Basic Structure of Tested Seat



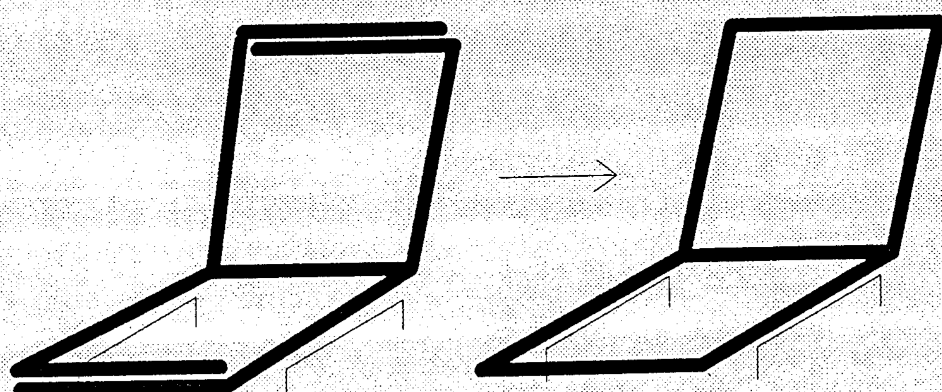
Method I: Double Horseshoes



Spring-Damper Torsional Element for Seat Back Hinge Joint Simulation

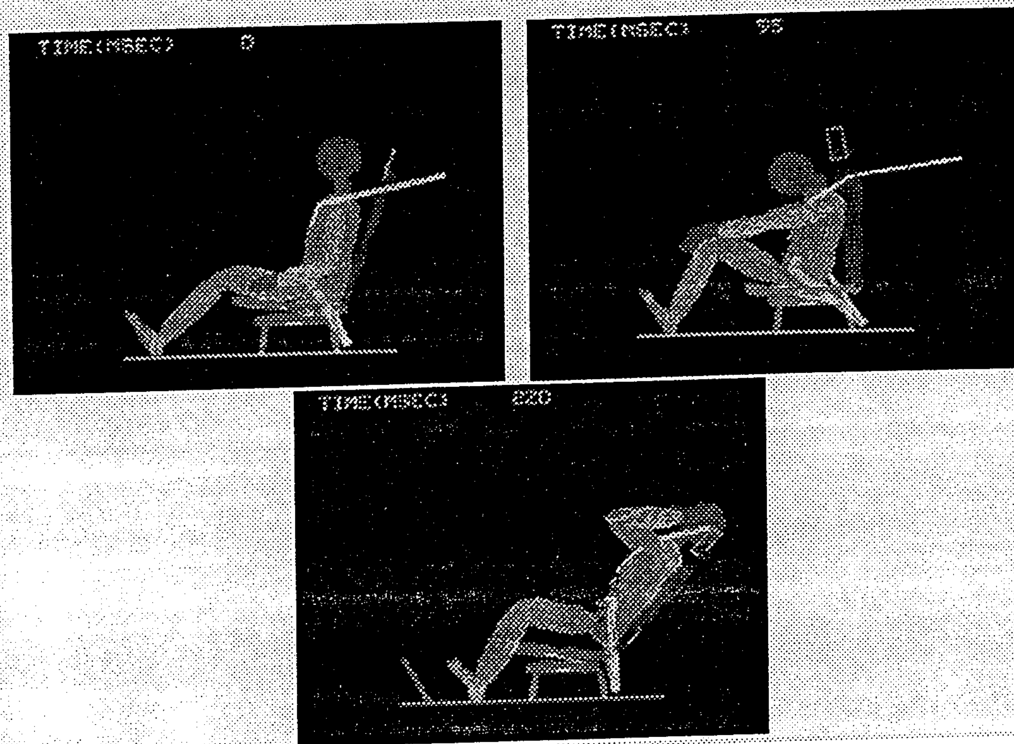


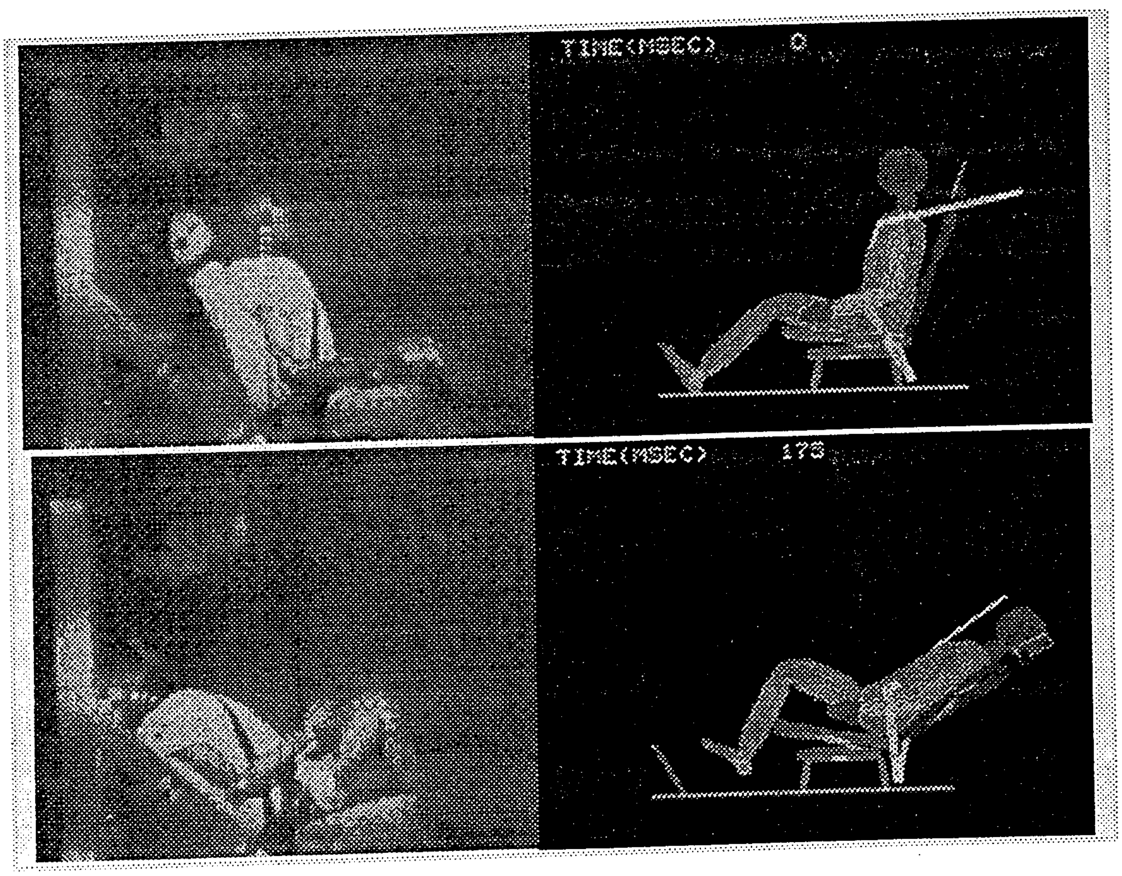
Method II: Coincident, Constrained Segments Simulating Closed Loops

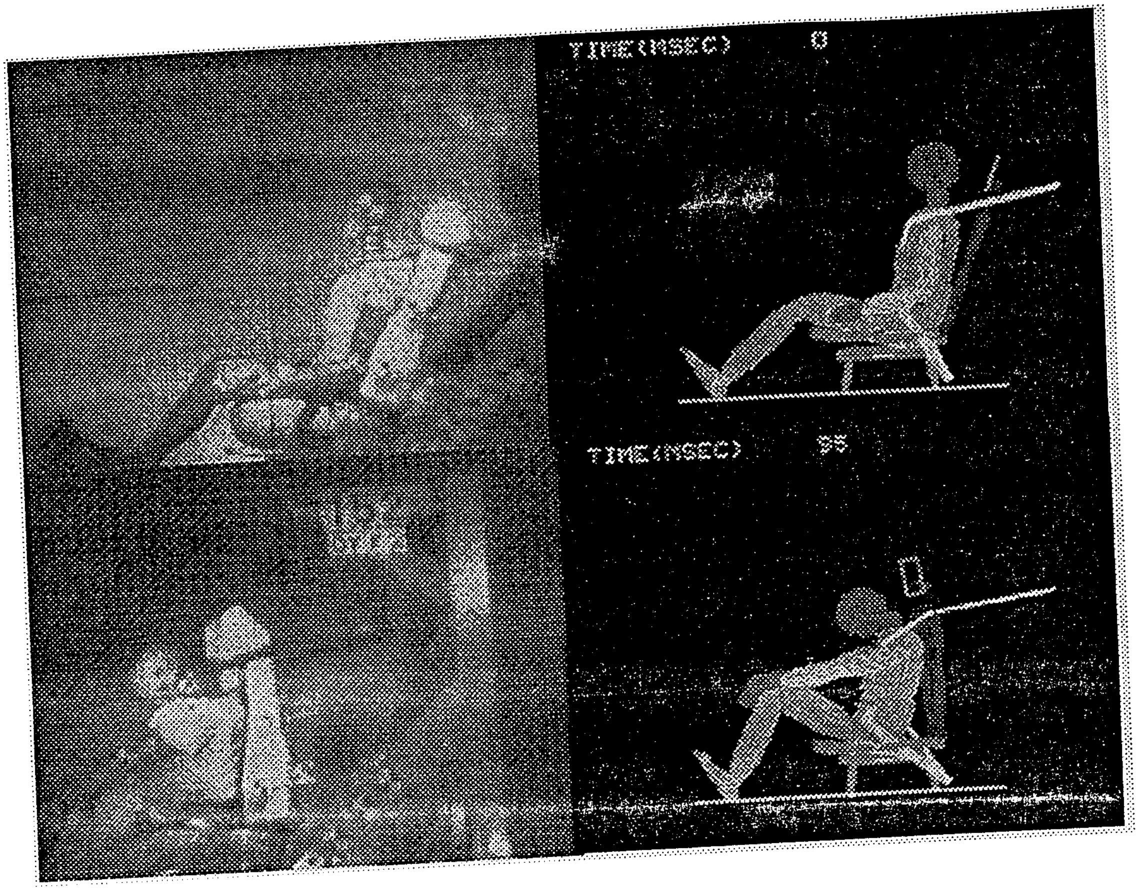


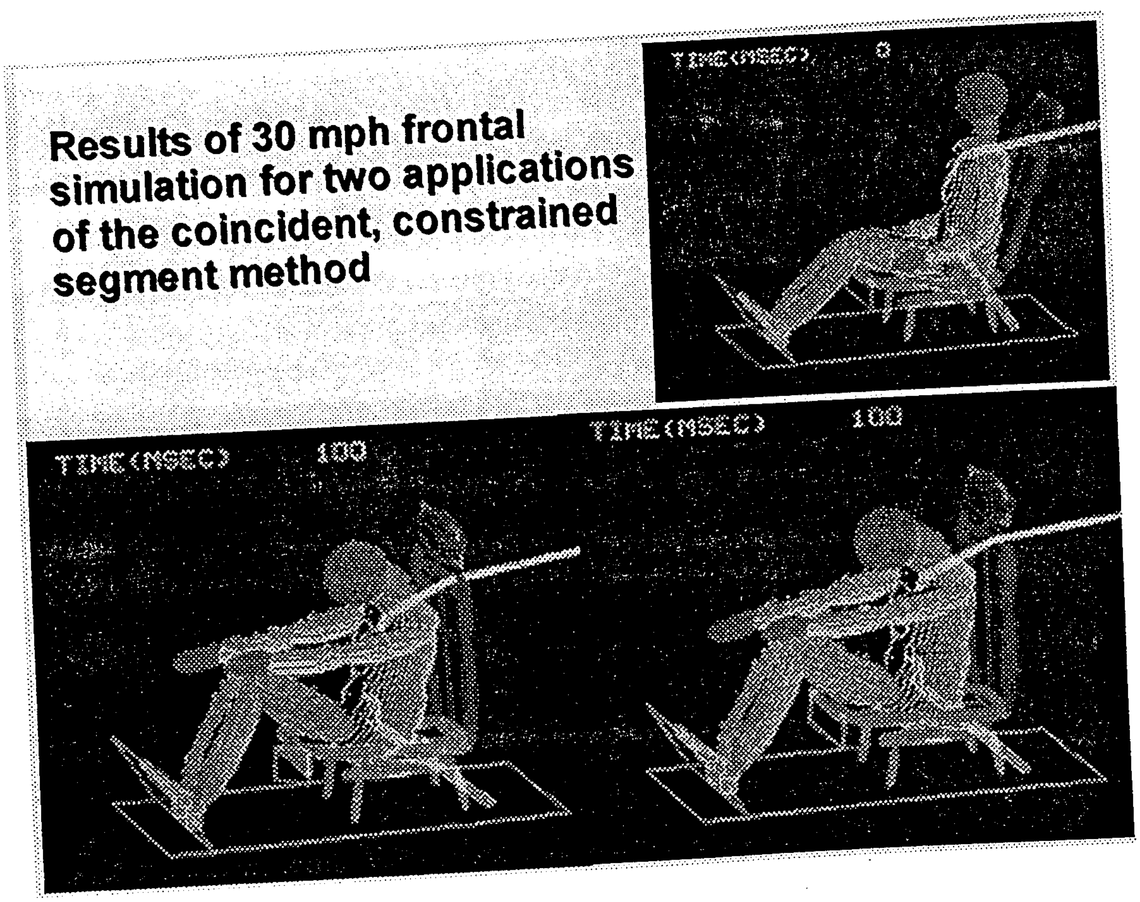
The Red and Blue segments at each end of the tree are locked together with point constraints from the D.6 cards. Three or more non-colinear points are used to obtain torsional as well as translational constraint.

Frontal Impact Simulation with Double-Horseshoe Seat









Results of 30 mph frontal simulation for two applications of the coincident, constrained segment method

NEW RESTRAINT BELT MODEL

Louise Obergefell
Armstrong Laboratory
Wright-Patterson Air Force Base, Ohio

CURRENT BELT MODELS

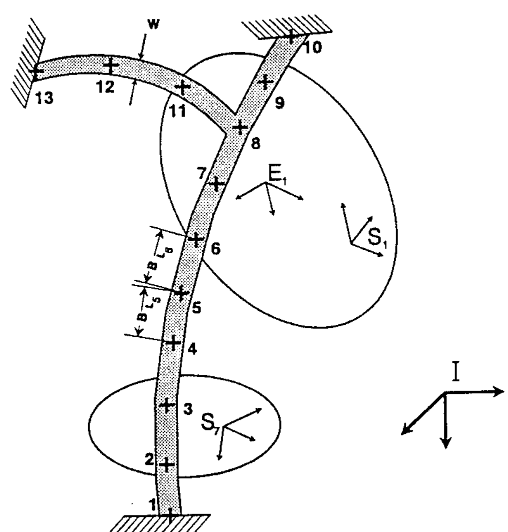
- Individual Spring Elements
- Interacting Spring Elements
  - Stress in one spring affects other springs
- ATB Harness
  - Series of belt segments
  - Endpoints move on one ellipsoid surface

OBJECTIVE

Develop, Implement, & Validate
Restraint Belt Model

- Applies Forces To The Body
- Uses Measured Material Properties
- Allows Slippage Of Belt On Body
- Includes Multiple Belts &
  Retraction Systems

RESTRAINT BELT CONFIGURATION

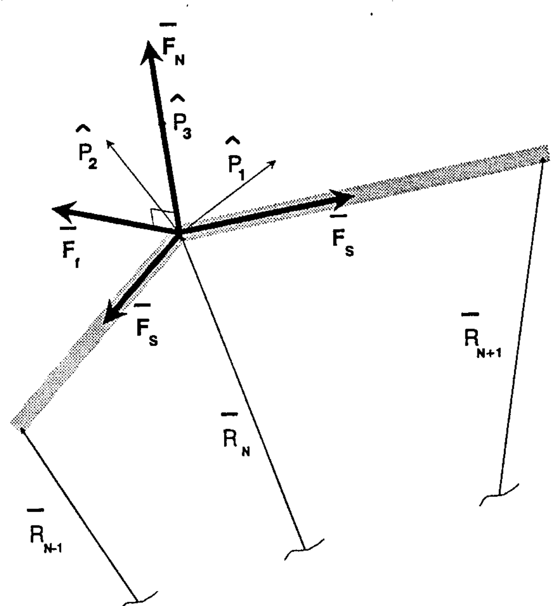


N	JPP(N)
1	0
2	1
3	2
4	3
5	4
6	5
7	6
8	7
9	8
10	9
11	8
12	11
13	12

FORCES AT BELT POINT

- Belt Stress Force
- Surface Deformation Force
- Friction Force

FORCES AT BELT POINT



FORCE BALANCE EQUATIONS

$$\sum F_{N_1}^{N} \cdot f_S(e_N,\dot{e}_N)\frac{r_{J_1}^{N}}{B_{L_N}} \cdot \sum_K f_S(e_K,\dot{e}_K)\frac{r_{K_1}^{N}}{B_{L_K}} - F_{f_{N_1}} \cdot E_{R_1}$$

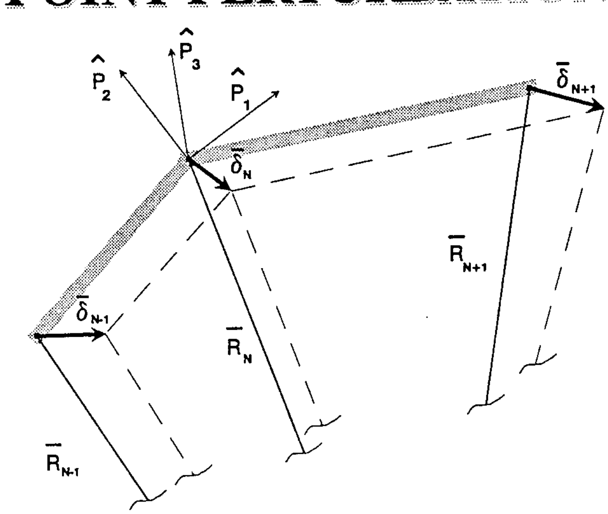
$$\text{if } F_{f_{N_{max}}} \geq \sqrt{F_{S_{N_1}}^2 \cdot F_{S_{N_2}}^2} \text{ then } E_{R_1} \cdot 0.0$$

$$\sum F_{N_2}^{N} \cdot f_S(e_N,\dot{e}_N)\frac{r_{J_2}^{N}}{B_{L_N}} \cdot \sum_K f_S(e_K,\dot{e}_K)\frac{r_{K_2}^{N}}{B_{L_K}} - F_{f_{N_2}} \cdot E_{R_2}$$

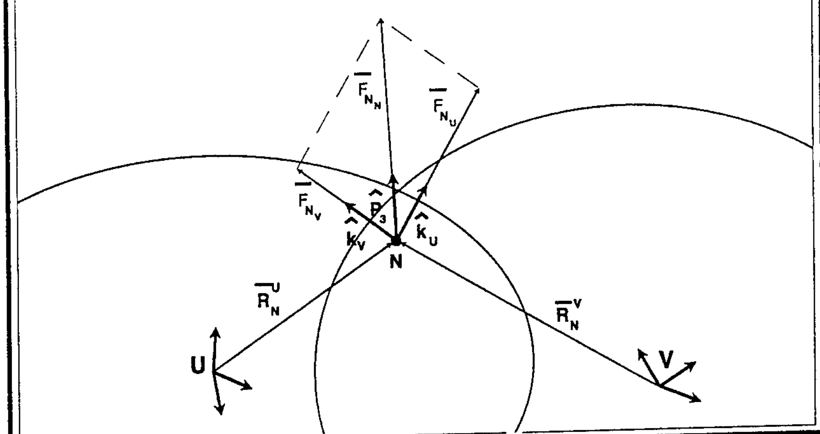
$$\text{if } F_{f_{N_{max}}} \geq \sqrt{F_{S_{N_1}}^2 \cdot F_{S_{N_2}}^2} \text{ then } E_{R_2} \cdot 0.0$$

$$\sum F_{N_3}^{N} \cdot f_S(e_N,\dot{e}_N)\frac{r_{J_3}^{N}}{B_{L_N}} \cdot \sum_K f_S(e_K,\dot{e}_K)\frac{r_{K_3}^{N}}{B_{L_K}} \cdot f_P(d_N,\dot{d}_N,m)W\, B_{H_N} \cdot E_{R_3}$$

POINT PERTURBATIONS



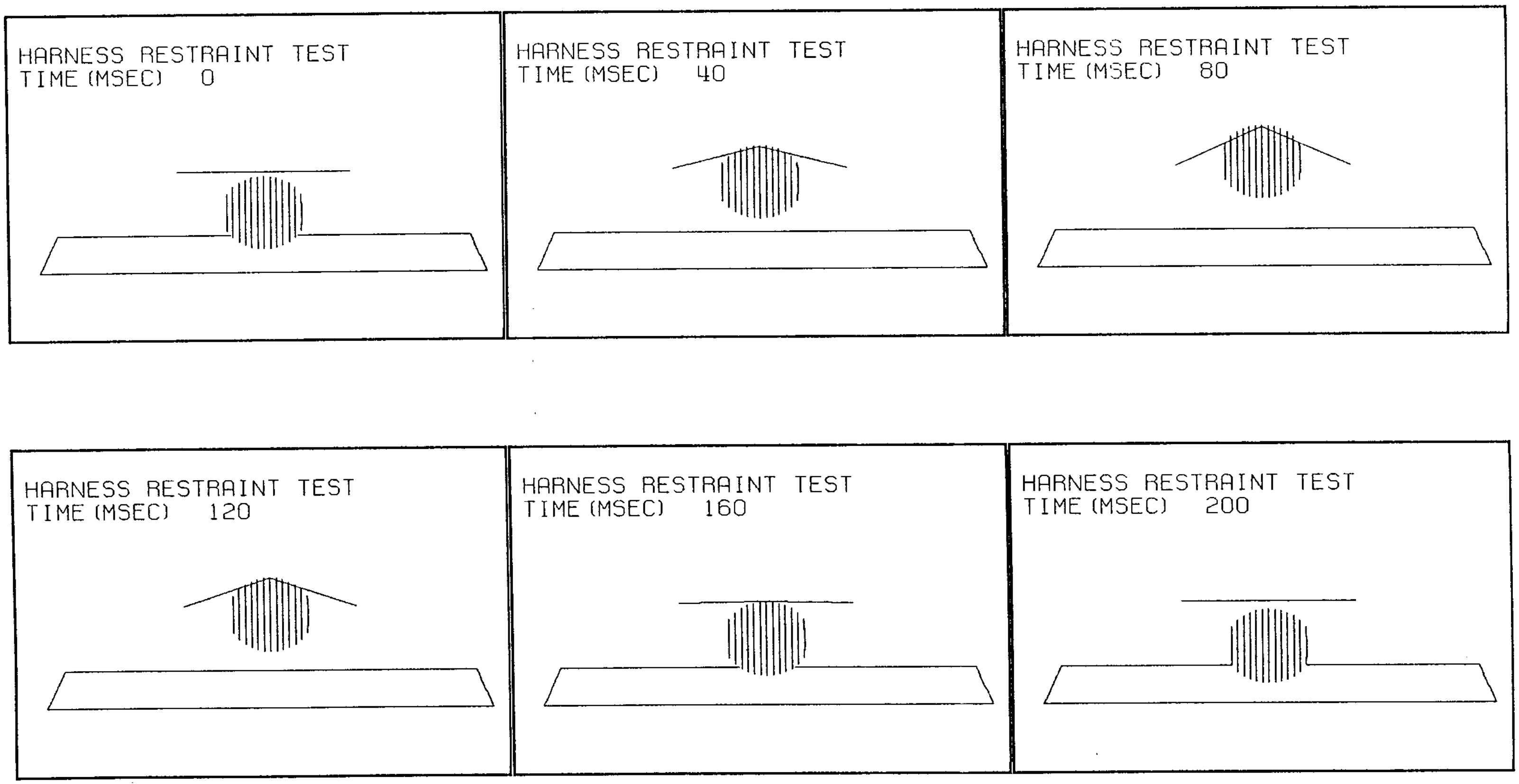
POINT CONTACT WITH TWO ELLIPSOIDS



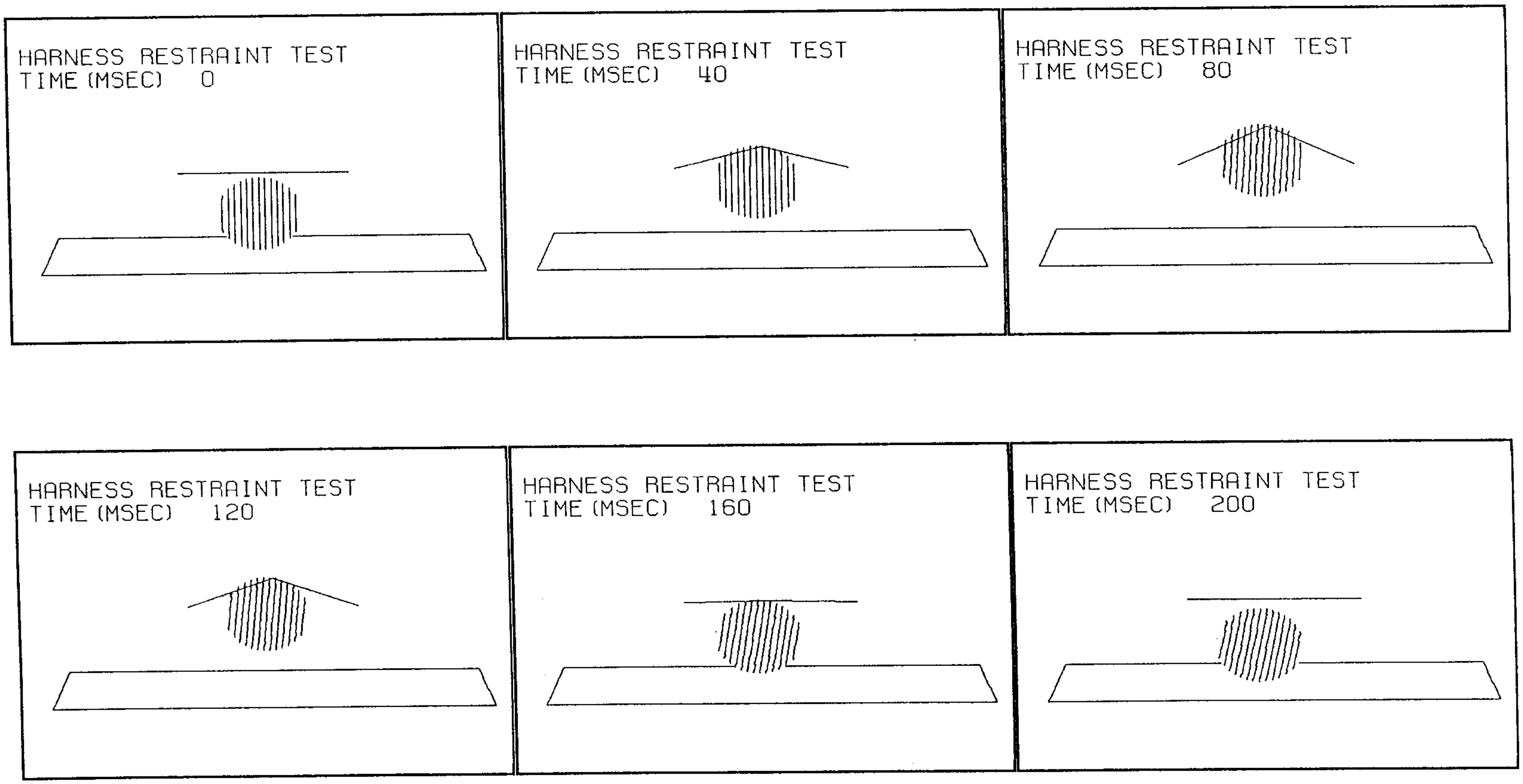
VALIDATION

- Elementary Simulations
  - One Free Point Belt
  - Multiple Free Point Belt
  - Buckle
  - Multiple Contact Ellipsoids
- Full Body Simulations
  - Sled Test Simulations

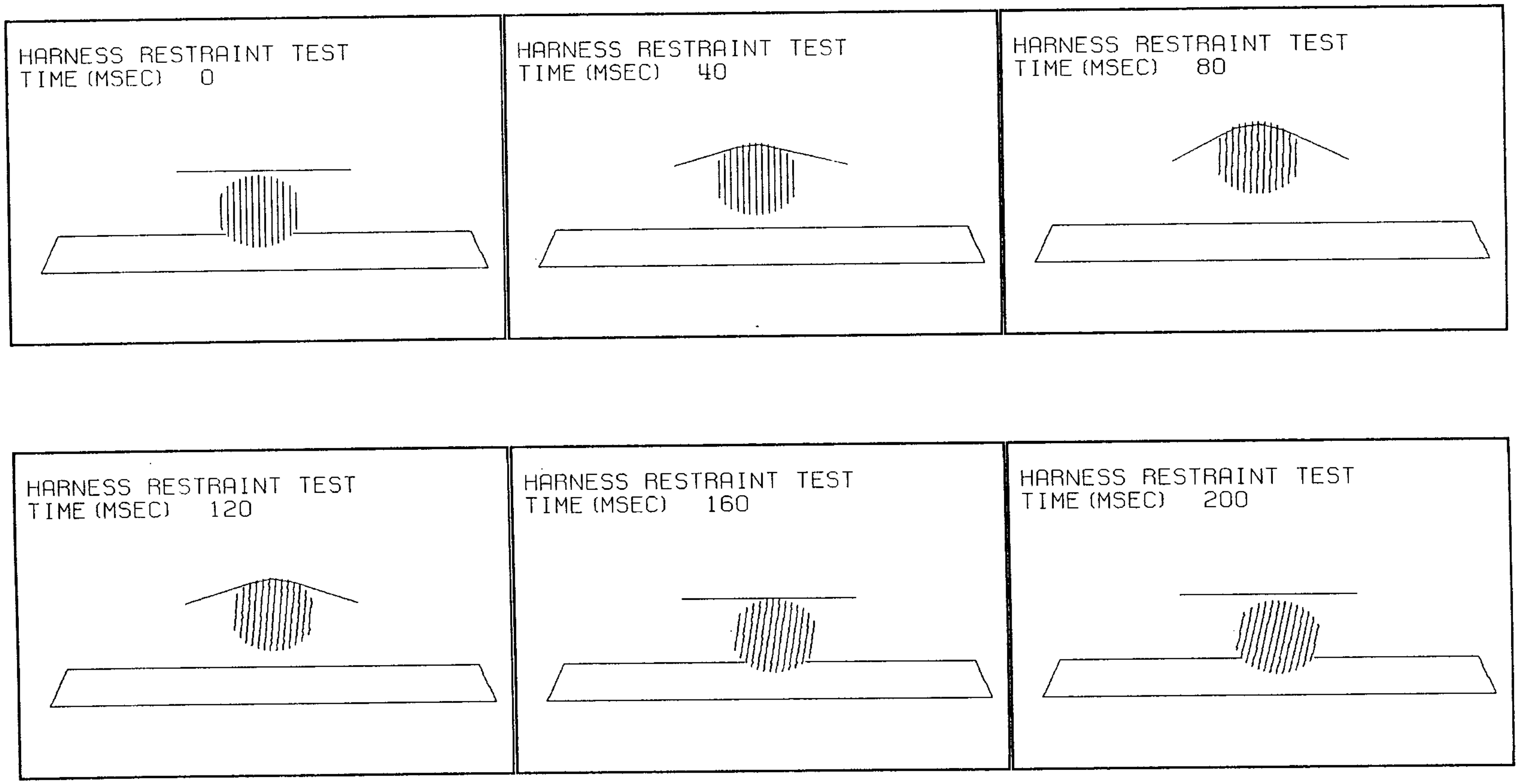
THREE POINT BELT SYMMETRIC



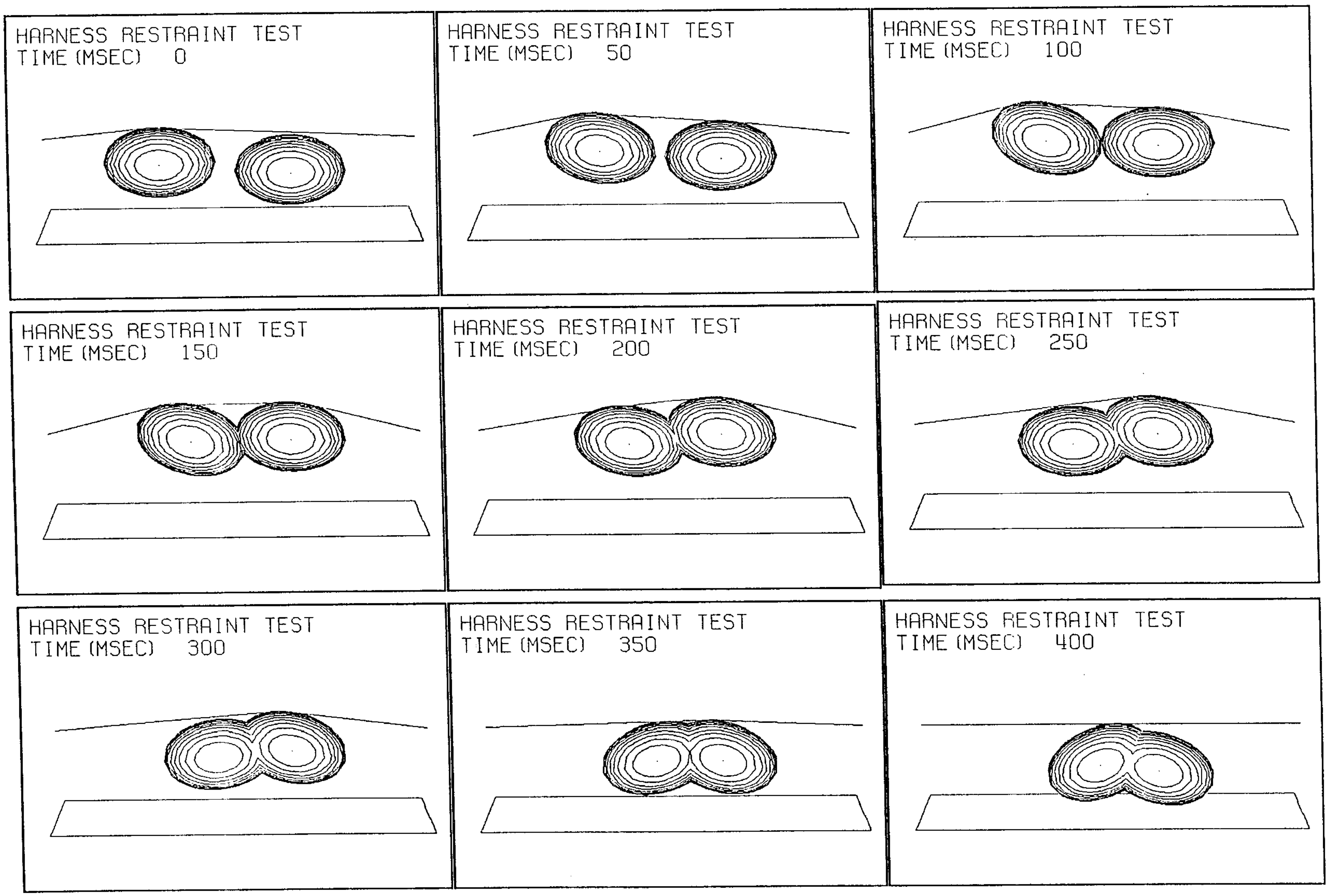
THREE POINT BELT OFFSET



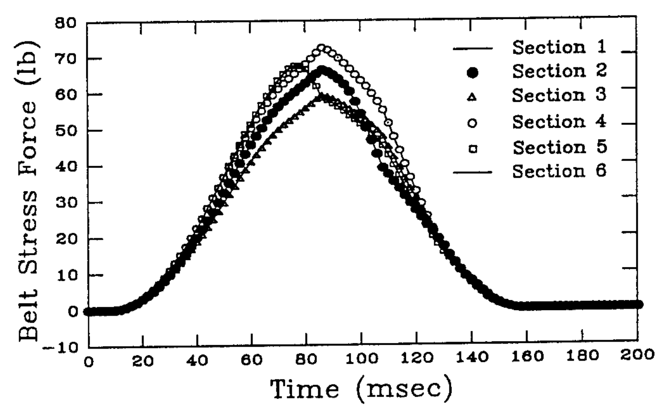
SEVEN POINT BELT OFFSET



TWO ELLIPSOIDS



STRESS FORCES IN BELT SECTIONS



RESTRAINT BELT INPUT

- Initial Point Locations
- Section Material Lengths
- Stress-Strain Properties
- Body Surface Pressure-Deflection Properties

CONCLUSIONS

- Restraint Belt Model Provides Reasonable Response
  - Belt Strain
  - Surface Deformation
  - Belt Slippage
    - Across multiple surfaces
  - Force Application
- Buckles & Other Mechanisms
- User Defined Belt & Surface Properties
- Converges Quickly in Most Cases

FUTURE EFFORTS

- Full Body Validations
- Check For Divergence & Modify Belt Equations
- Method for Obtaining Initial Conditions
- Additional Belt Mechanisms

Using the ATB Model Coupled with MSC/DYTRAN for Cockpit Air Bag System Development

David Furey
Simula Government Products, Inc.

95252- 1

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Government Products, Inc.

Simula's ATB Experience

- Have used ATB for seven years
- Modeled occupant responses in helicopter crash conditions
- Other applications

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Cockpit Air Bag Systems (CABS) Development

- Designed to protect aircrew from various cockpit strike hazards
  - Telescopic sighting unit (TSU)
  - Cyclic stick
  - Armor
  - Others

95252- 3

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CABS Modeling Requirements

- Model occupant's gross motion
- Simulate the correct deployment trajectory of the folded air bag
- Simulate the occupant/cockpit/air bag interaction

95252- 4

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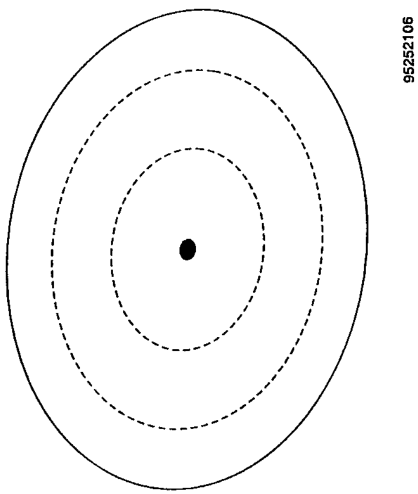
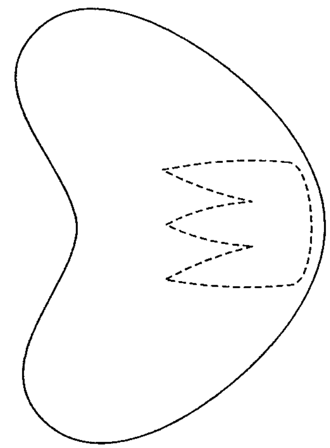
Air Bag Deployment Modeling

ATB V4.4 air bag segment	CABS requirement
	
Expanding ellipsodial shape	Arbitrary deploying shape

- The ATB air bag element is inadequate for the CABS simulation because the air bag deployment trajectory is highly dependent on the folding pattern

95252- 5

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MSC/DYTRAN

- 3-D analysis code for analyzing the dynamic non-linear behavior of solid components, structure, and fluids

- Capable of modeling air bag deployment
  - Arbitrary bag shape and folding pattern
  - Uniform pressure or full gas dynamics (Eulerian) inflation

- Newly developed link to the ATB code for occupant simulation/interaction

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MSC/DYTRAN - ATB Contact Interface

- Two methods:
  - (1) The ATB segments are represented as rigid ellipsoids in DYTRAN, which are allowed to contact other DYTRAN elements
  - (2) DYTRAN shell elements are "attached" to the ATB segments, which are allowed to contact other DYTRAN elements

95252- 7

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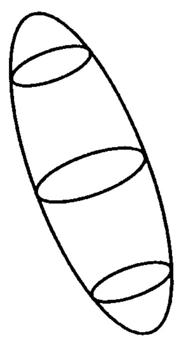
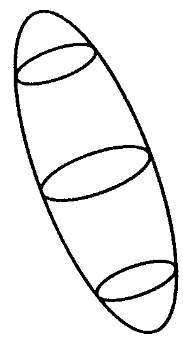
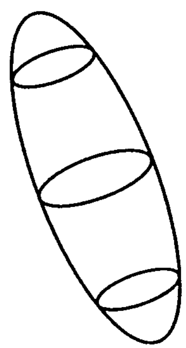
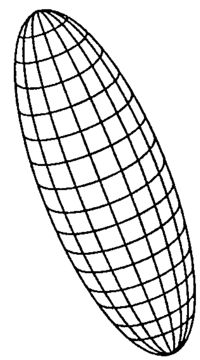
ATB		DYTRAN	
 95252104	Method 1	 95252104	• Can contact other rigid ellipsoids, shell and membrane elements
Ellipsoidal contact segment		**Rigid ellipsoid**	
 95252104	Method 2	 95252102	• Can contact other rigid ellipsoids, shell and membrane elements • Can define friction
Ellipsoidal contact segment		**DYTRAN shell elements**	

95252- 8

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CABS Simulation

- A case was modeled using MSC/DYTRAN - ATB
  - ATB 95th-percentile human male model
  - Strike hazards and air bags modeled using DYTRAN
  - Seat/floor occupant interaction modeled in ATB
  - Stroking seat mechanism modeled using ATB segments
  - Occupant/seat force deflection modeled in ATB

95252- 9

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CABS Simulation Model

Components	Modeled
Occupant	ATB
EA/Rail	ATB
Floor, Seat	ATB
Restraint System	ATB
TSU	DYTRAN
Air Bags	DYTRAN

95252- 10

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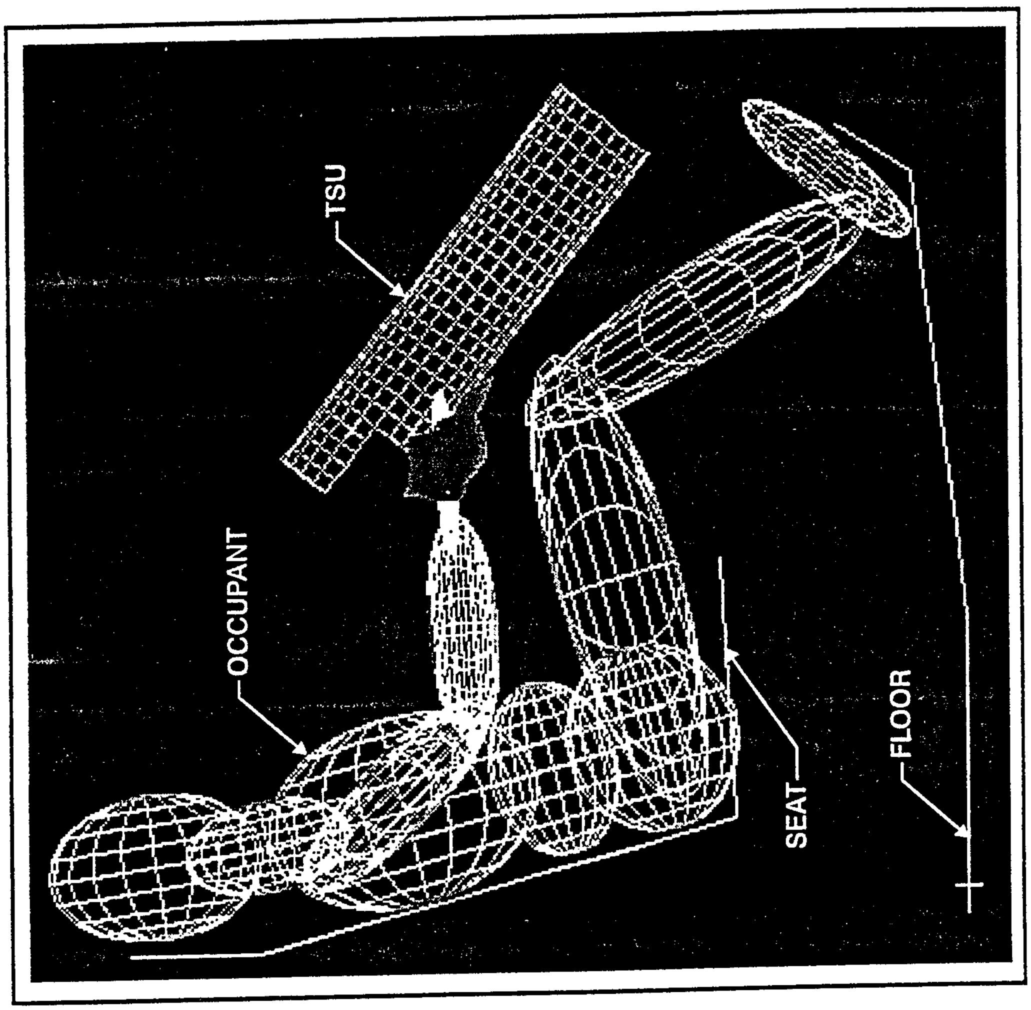
95252103



Crash Pulse Application

- Two Methods:

  (1) Prescribe a deceleration pulse using ATB Card C.2.a

  (2) Apply an acceleration field to the ATB segments via MSC/DYTRAN

95252- 11

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Simulation Results

- Test case: 30-G longitudinal crash pulse
  - ATB occupant interacts with the DYTRAN air bag
  - Occupant does not strike the TSU
  - HIC and head acceleration output from ATB

95252- 12

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Summary

- The MSC/DYTRAN - ATB link works well for occupant/air bag/structure interaction

95252- 14

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Further Enhancements

- New MSC/DYTRAN features
  - Belt elements
  - Belt pre-tensioners
  - Digitized dummy models

95252- 15

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Suggested ATB Enhancements

- Add the ability to model more occupants (increase the number of segments)

- Add a robust restraint system

95252- 16

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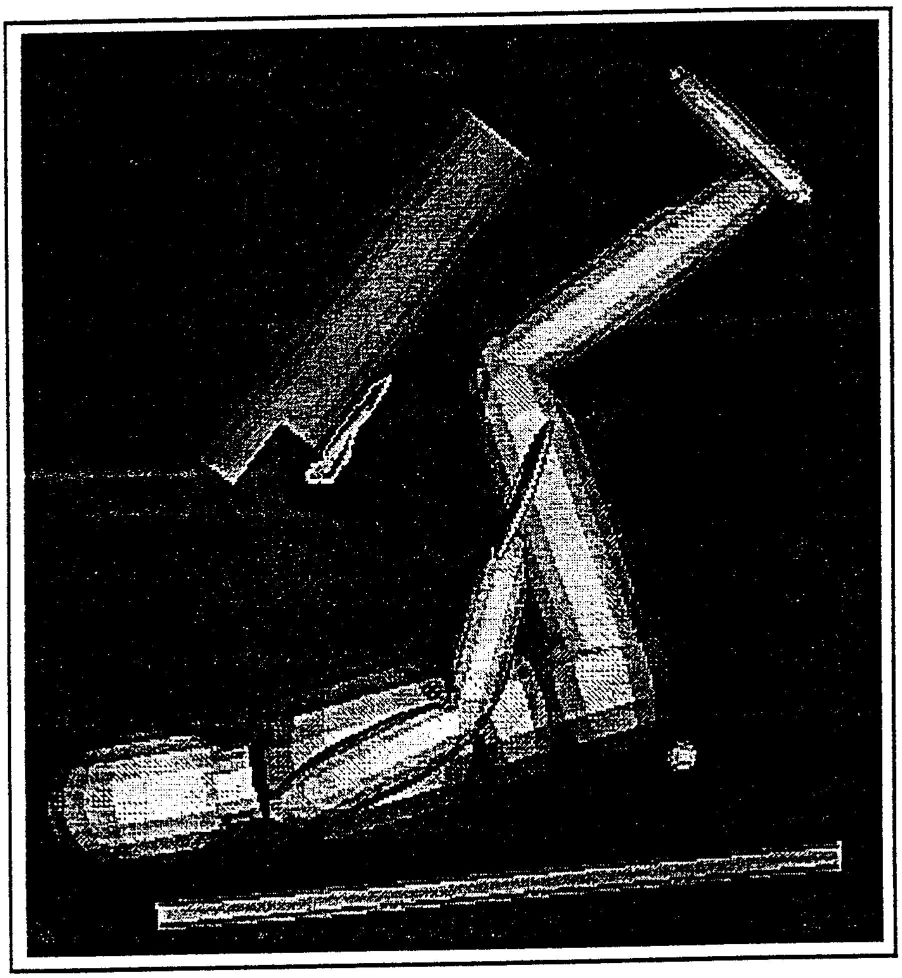

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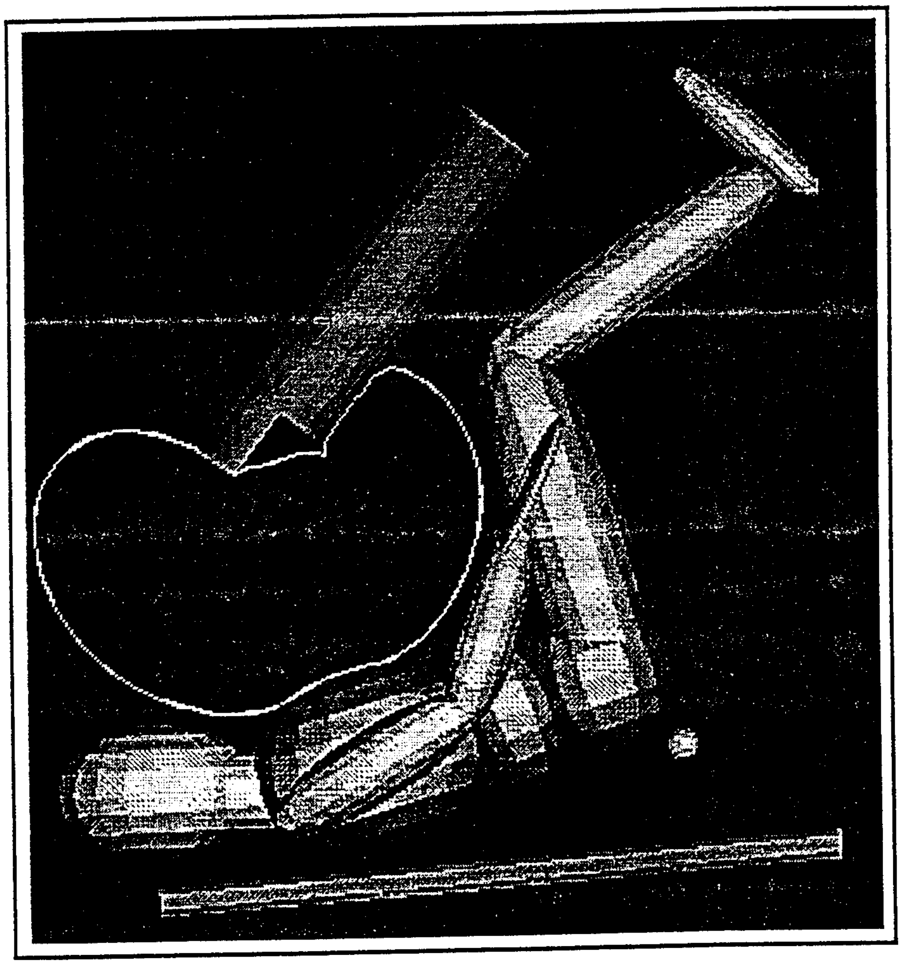

Integration of the ATB Occupant Model in MSC/DYTRAN

Methodology & Validation

Arjaan Buijk
The MacNeal-Schwendler Corporation
June 13, 1995

The MacNeal-Schwendler Corporation

MSC/DYTRAN Features

- *Explicit finite element solver*
- *Complete library of finite elements and constitutive models*
- *Robust & efficient 3D contact algorithm*
- *Fully integrated ATB occupant model*
- *Pre/post processing with MSC/PATRAN*
- *Input compatibility with MSC/NASTRAN*

The MacNeal-Schwendler Corporation

1995 ATB Users' Colloquim

Benefits of ATB in MSC/DYTRAN

- proven ATB occupant kinematics combined with MSC/DYTRAN for modeling of:
  - realistic occupant shape
  - deformable finite element occupant surroundings (dashboard, seat, doors, windshield, etc)
  - contact between ATB and deformable surroundings
  - belt restraint allowing arbitrary frictional contact with ATB, including possible release away from the ATB occupant followed by re-contact

Benefits of ATB in MSC/DYTRAN
(continued)

- *arbitrary airbag shape with uniform pressure <u>or</u> non-uniform Eulerian gas dynamics inflation models*
- *graphical positioning of ATB occupant model using MSC/PATRAN*
- *results processing and visualization with commercially available tools, such as MSC/PATRAN and The Data Visualizer*

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Integration of ATB in MSC/DYTRAN

Methodology

ATB input file

*.ain

MSC/DYTRAN input file

*.dat

MSC/DYTRAN

.AOU,.TP1,*.TP8,*.ARC,*.THS

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Integration of ATB in MSC/DYTRAN

Methodology

- MSC/DYTRAN finite elements can be arbitrarily attached to ATB segments
- MSC/DYTRAN finite elements can contact ATB ellipsoids
- Acceleration pulse can be directly applied to ATB segments from within an MSC/DYTRAN input deck

MSC The MacNeal-Schwendler Corporation

1995 ATB Users' Colloquim

Positioning of ATB Occupant Model

- ATB occupant model can be graphically positioned within MSC/PATRAN

- New occupant position automatically supplied to MSC/DYTRAN to perform coupled ATB-MSC/DYTRAN analysis

Visualization of Coupled ATB-MSC/DYTRAN Results

- ATB output requests on Hxx cards are automatically converted to MSC/DYTRAN time-history output files
- ATB ellipsoids are automatically coated with MSC/DYTRAN dummy shell elements for visualization purposes
- Coupled ATB-MSC/DYTRAN results can then be easily visualized using a commercial tool such as MSC/PATRAN

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1995 ATB Users' Colloquim

Development of Enhanced 50% HYBRID III ATB Occupant Model

- *Funded joint project between MSC and HimaTech in Detroit*
- *ATB inertia and joint properties generated with GEBOD*
- *Exact geometry of HYBRID III dummy digitized and represented using MSC/DYTRAN shell elements, which are then attached to ATB segments*

Validation of Enhanced 50% HYBRID III ATB Occupant Model

Validated against Ford Motor Co. sledtests

Occupant kinematics - ATB

Sled model - ATB rigid planes

Occupant/sled interaction - ATB contact

Occupant positioning - MSC/PATRAN

Lap & shoulder belts - MSC/DYTRAN

Belt pretensioning - MSC/DYTRAN

Occupant/belt interaction - MSC/DYTRAN contact

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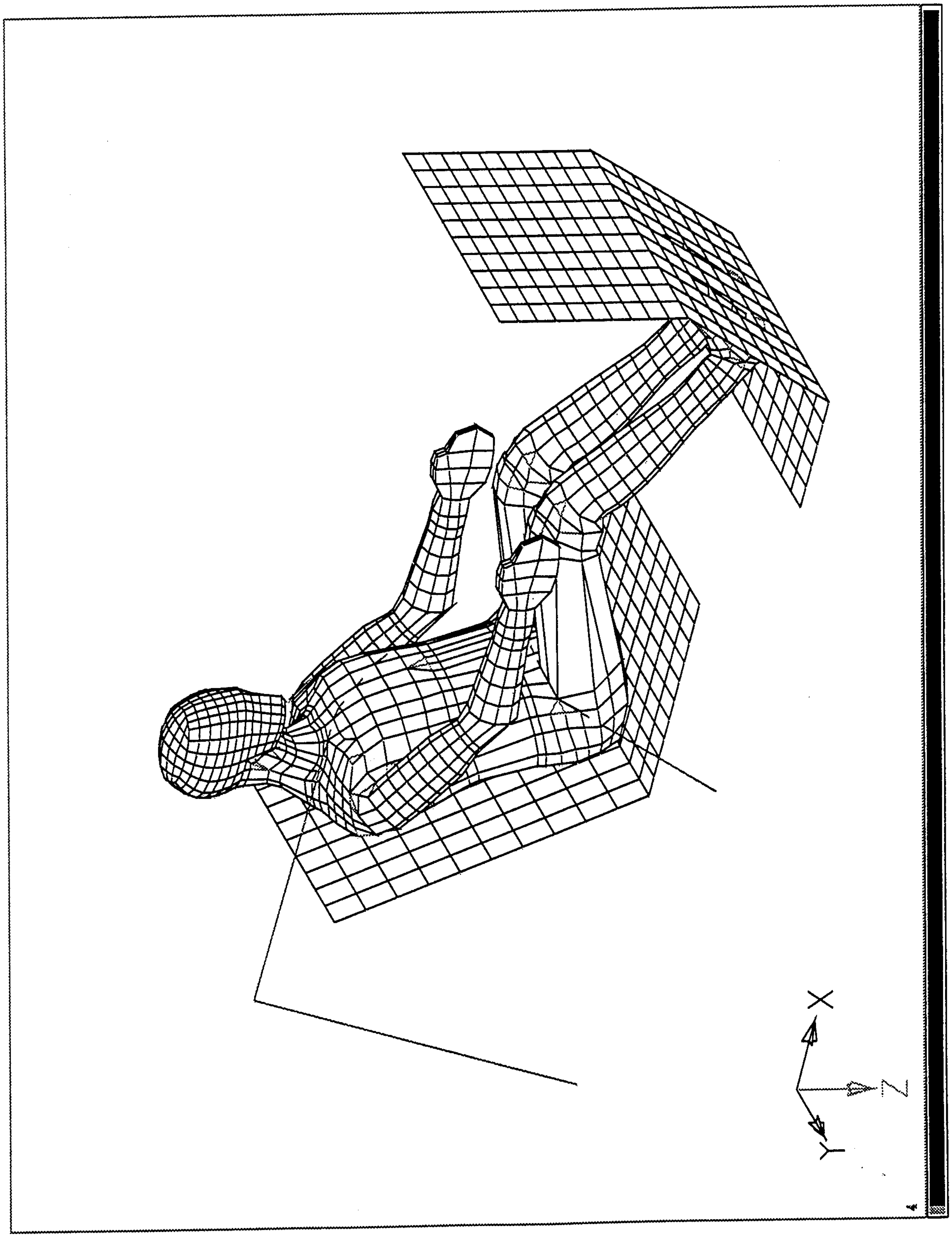
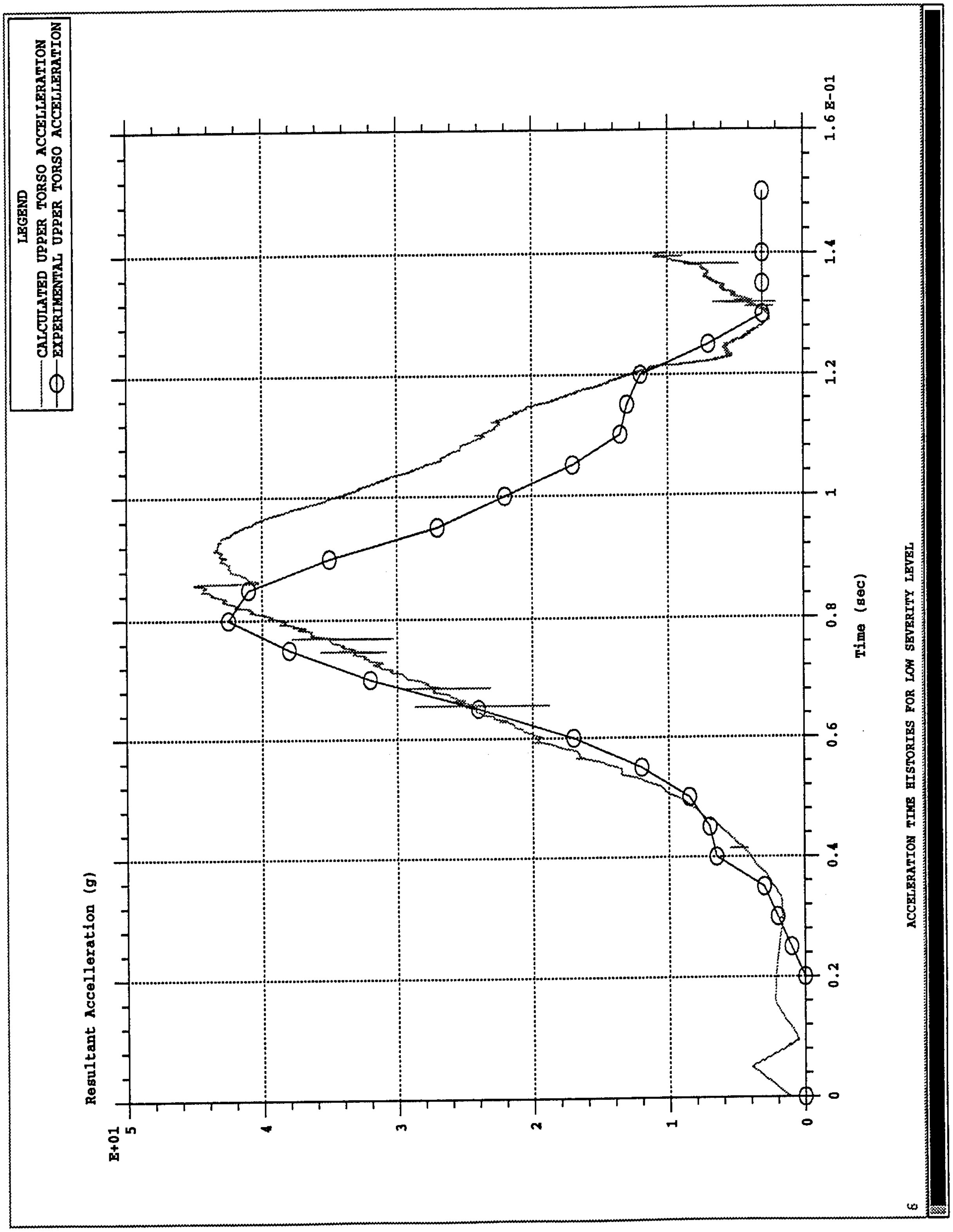
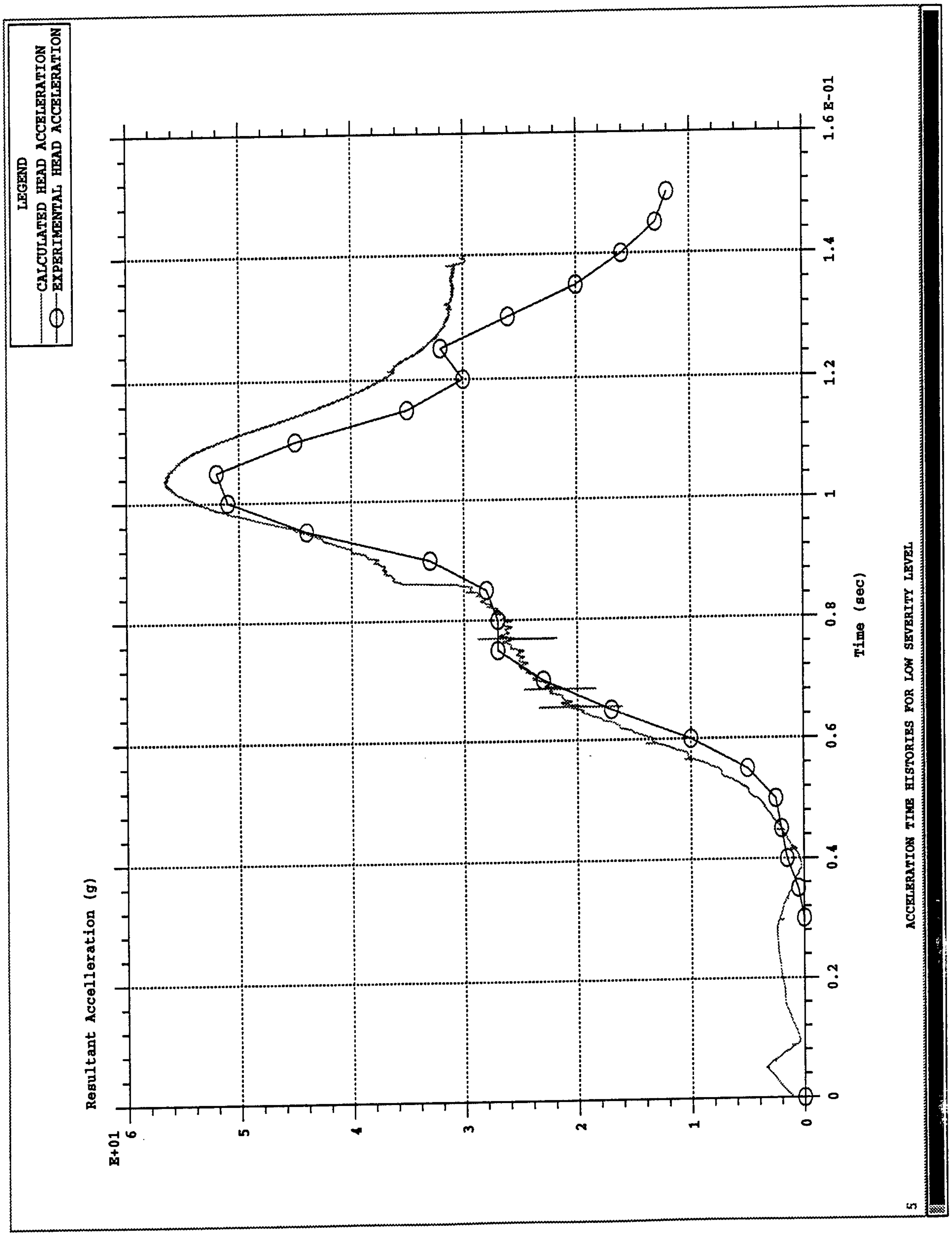
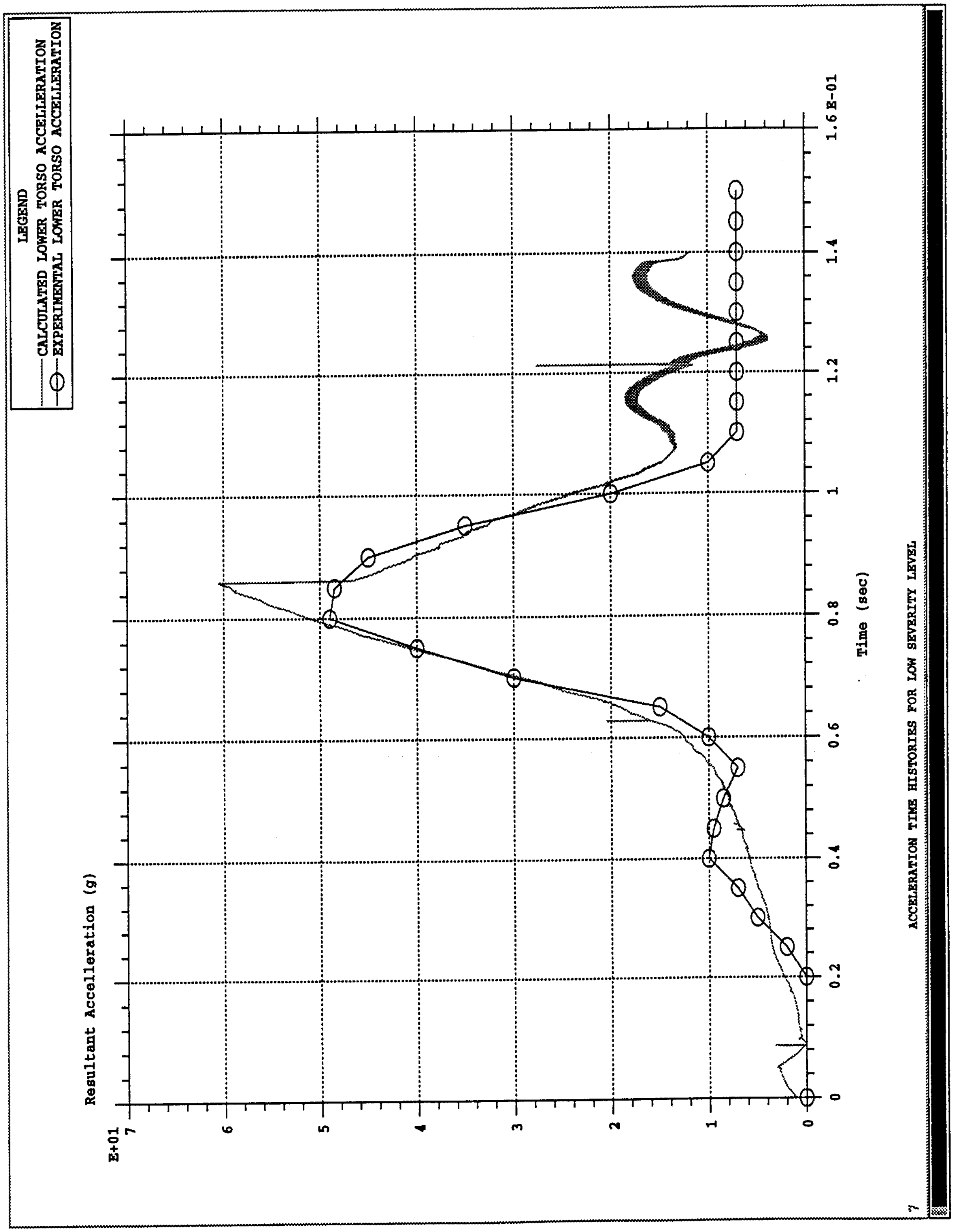

X
Z
Y



ACCELERATION TIME HISTORIES FOR LOW SEVERITY LEVEL



ACCELERATION TIME HISTORIES FOR LOW SEVERITY LEVEL



ACCELERATION TIME HISTORIES FOR LOW SEVERITY LEVEL

ATB Applications in Helicopter Crashworthiness

Lindley W. Bark

Simula Government Products, Inc.

13 June 1995

The 1995 ATB Model Users' Colloquium

95258- 1

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Helicopter Crash Characteristics

- Wide range of pitch and roll conditions
- Substantial vertical impact velocities
- Vertical displacement of the occupant
- Vertical compression of the seat structure, cushion, and occupant's torso
- Lack of adequate restraint

95258- 2

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ATB Model Applications

- Energy-absorbing seating
  - Assessment of restraint system performance
  - Assessment of strike hazards
  - Definition of air bag system timing criteria

- Auxiliary fuel cell retention study

95258- 3

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Energy-Absorbing (EA) Seating

- Protects occupant's lumbar spine in the event of an impact with injurious vertical velocity changes and/or accelerations

- Limits the vertical acceleration of the occupant through controlled vertical displacement of the seat relative to the aircraft

95258- 4

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EA Seat Simulation With ATB

- Model EA characteristics
- Allow adequate occupant motion within the restraint
- Compared with results from SOM-LA program

95258- 5

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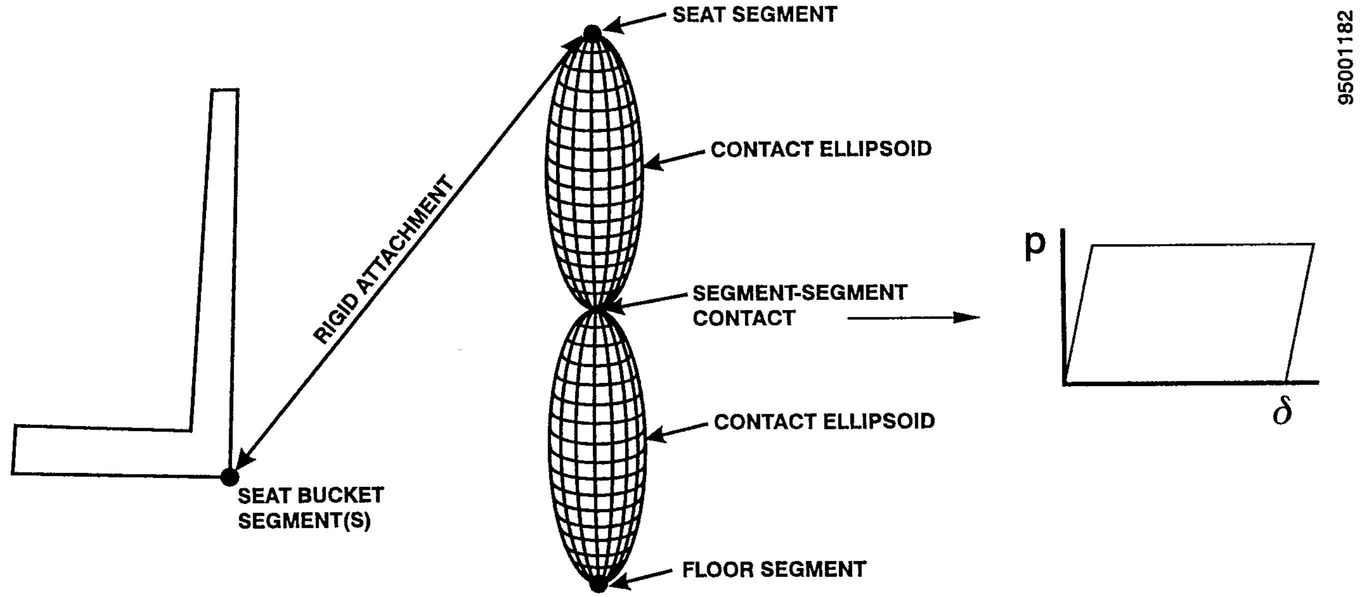
EA Model



- 1-D slip joint between seat and floor segments
- Initial velocity prescribed for floor and seat segments
- Acceleration prescribed for floor segment

95258- 6

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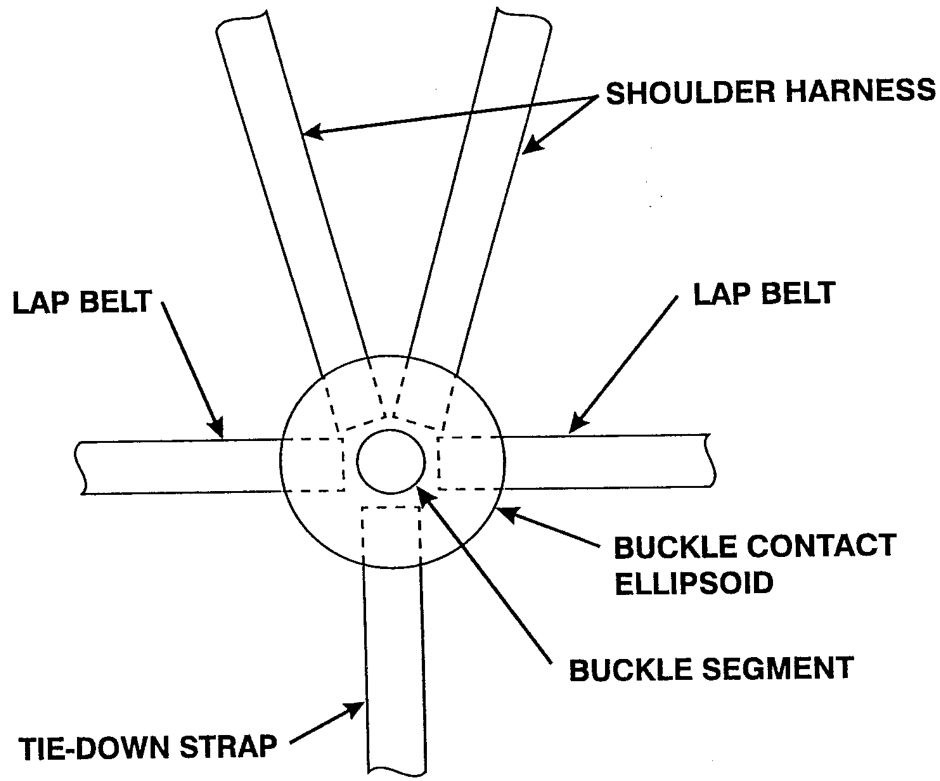
Restraint Buckle Model

- Buckle contact with occupant
- Initial velocity must be prescribed for buckle segment



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95258- 7

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Compare with Validated Model

- SOM-LA successfully used as a design tool in EA seat design

- SOM-LA is weak in the area of considering multiple contacts and other devices such as air bags

95258- 8

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Dynamic Conditions

- Pulse 1 - Pure Sled
- Pulse 2 - Combined Vertical
  - Vertical Drop, -30-deg pitch, 10-deg roll
- Pulse 3 - Pure Lateral
- Pulse 4 - Pure Vertical

95258- 9

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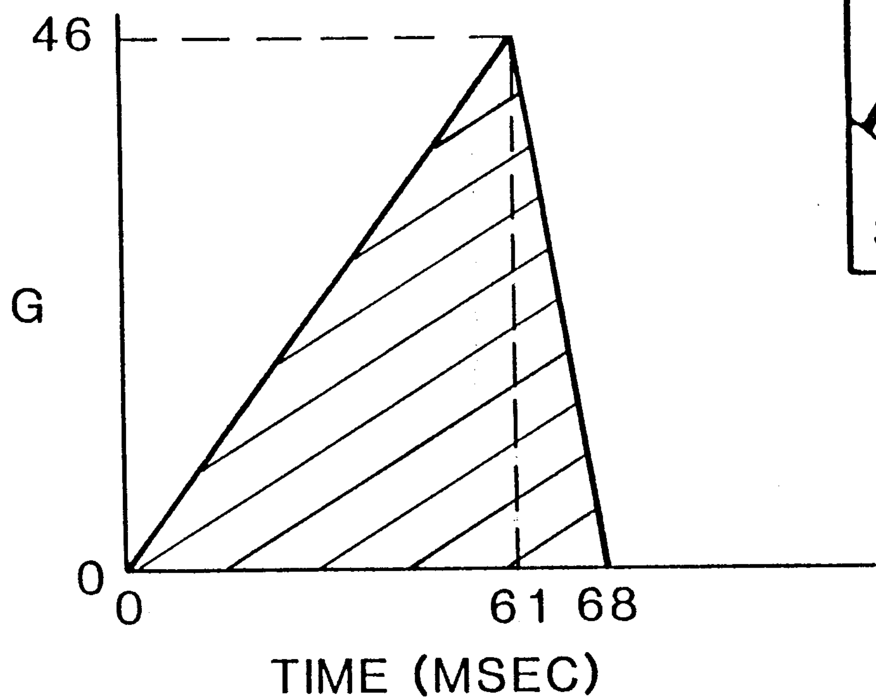
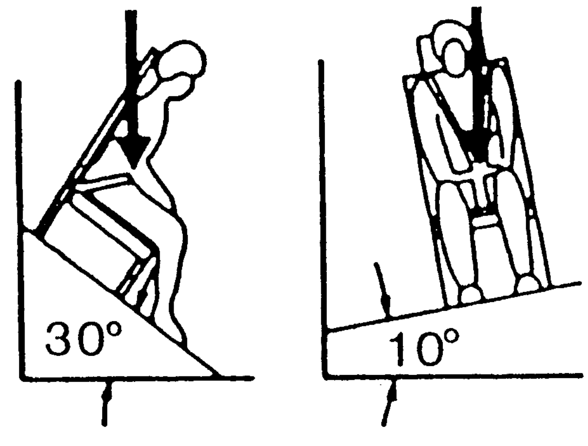
Crash Pulse 2

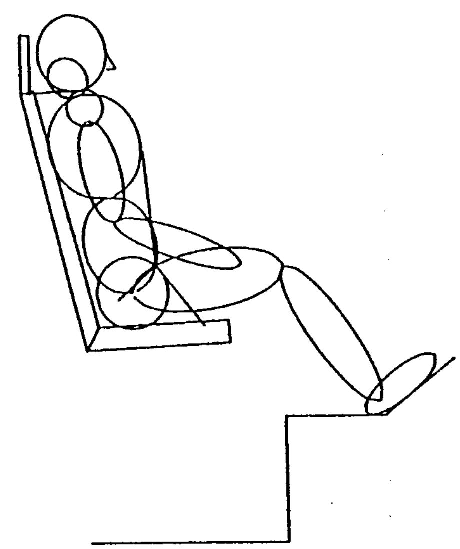




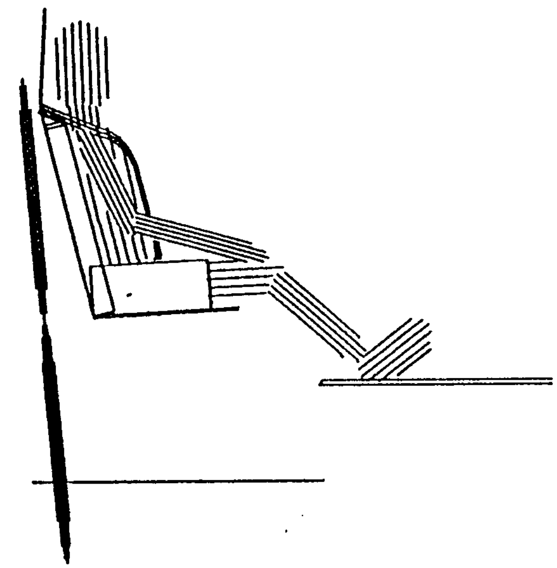
$\Delta V = 50$ FT/SEC

91 05001 18

Occupant dynamic responses for Pulse 2



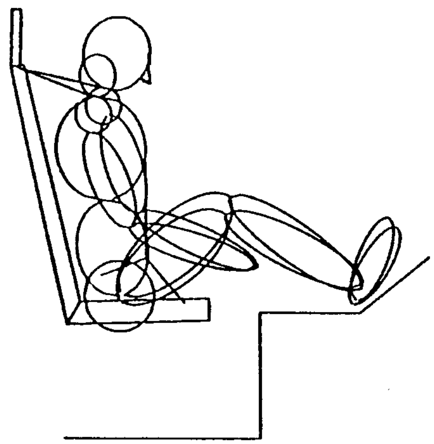
SOM-LA



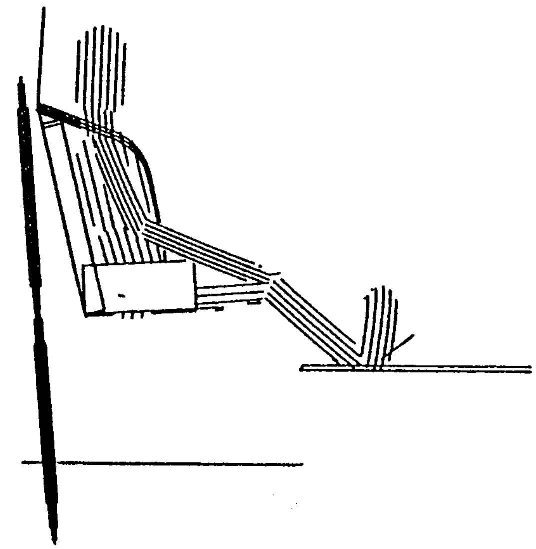
ATB model

Time = 0 msec

Occupant dynamic responses for Pulse 2 (contd)



SOM-LA

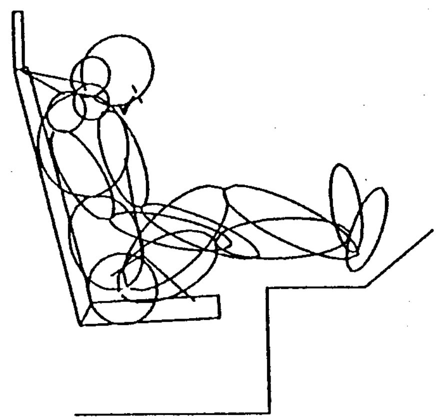


ATB model

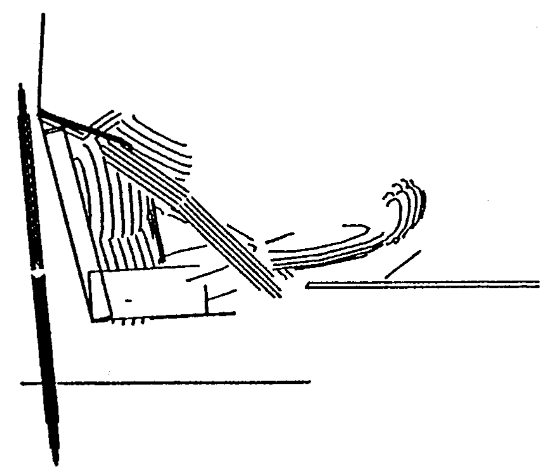
Time = 50 msec

91 05001 25

Occupant dynamic responses for Pulse 2 (contd)



SOM-LA

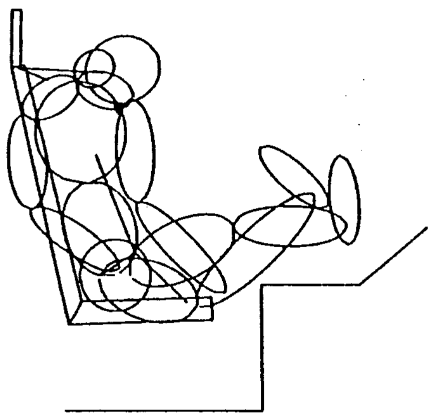


ATB model

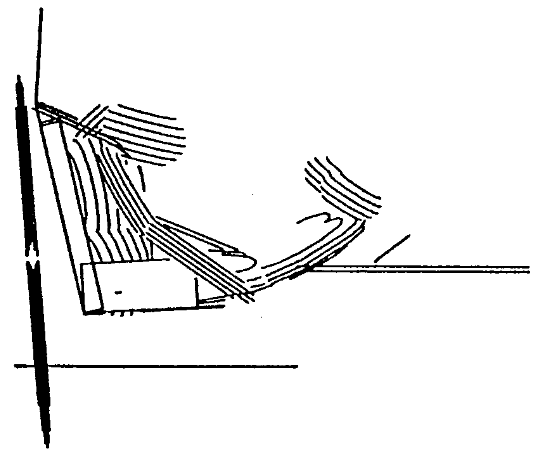
Time = 100 msec

91 05001 26

Occupant dynamic responses for Pulse 2 (contd)



SOM-LA

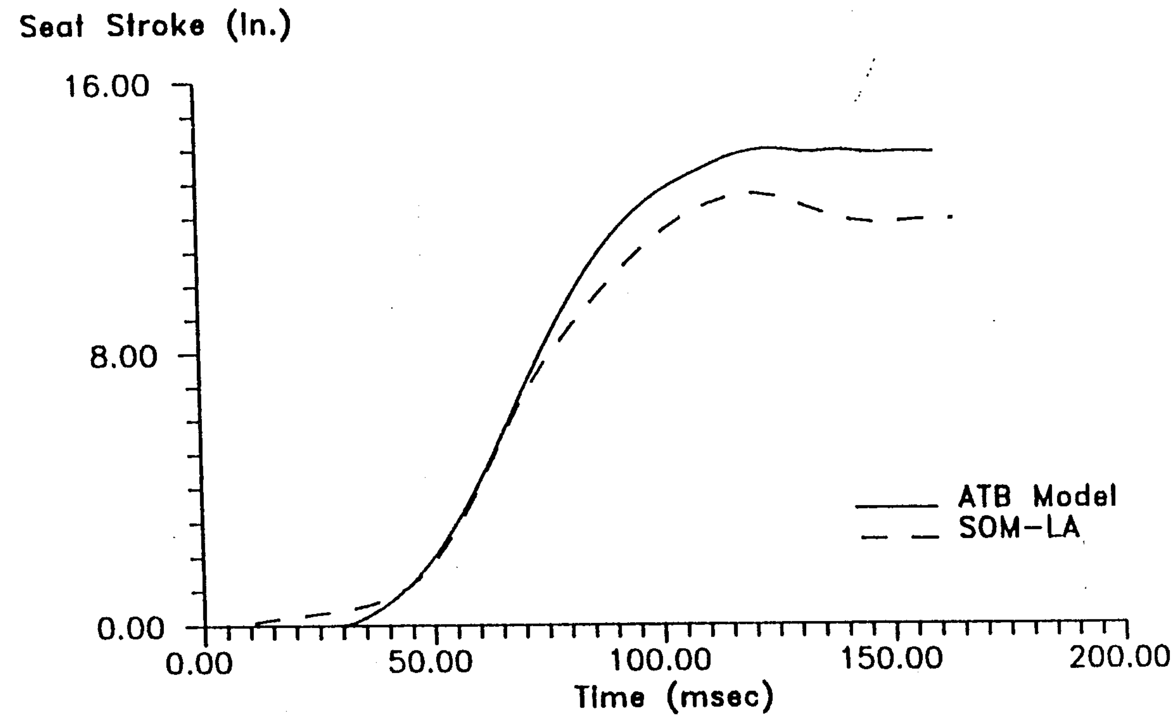


ATB model

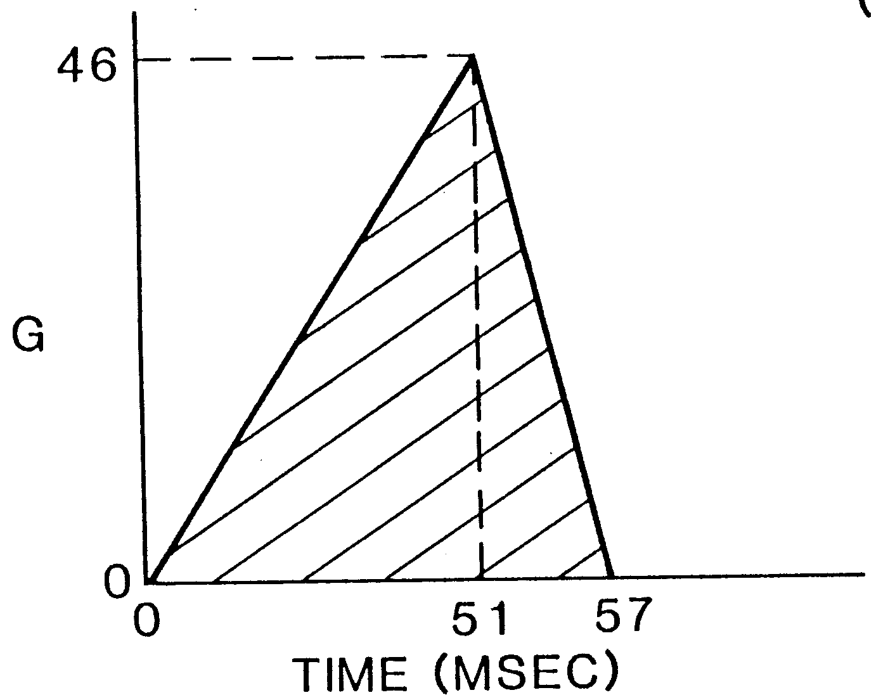
Time = 140 msec

91 05001 27

Predicted seat strokes for Pulse 2



Crash Pulse 4

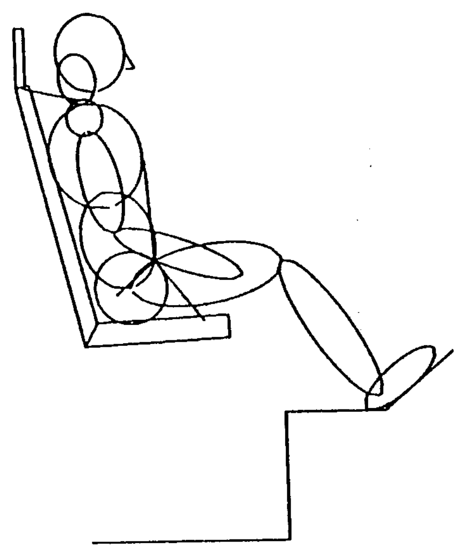


VERTICAL ACCELERATION
(EYEBALLS DOWN)

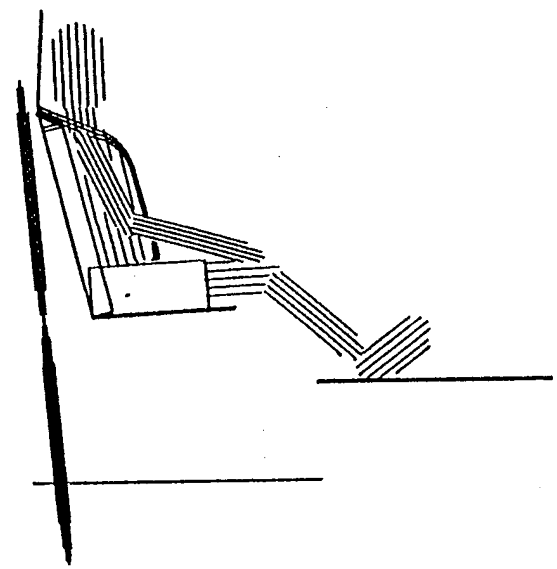
$\Delta V = 42$ FT/SEC

91 05001 34

Occupant dynamic responses for Pulse 4



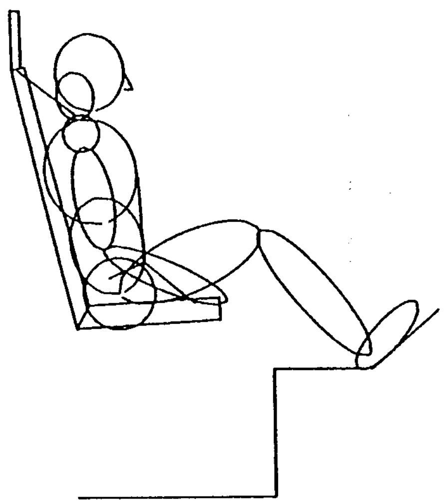
SOM-LA



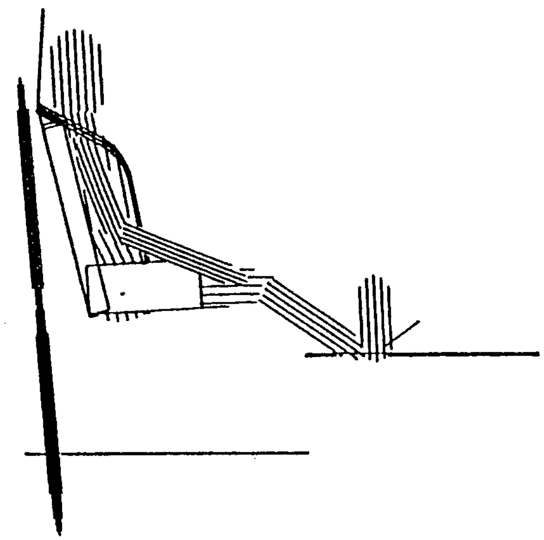
ATB model

Time = 0 msec

Occupant dynamic responses for Pulse 4 (contd)



SOM-LA

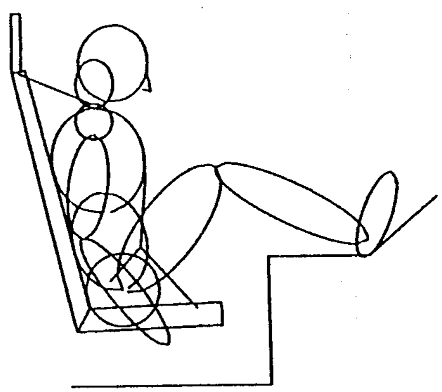


ATB model

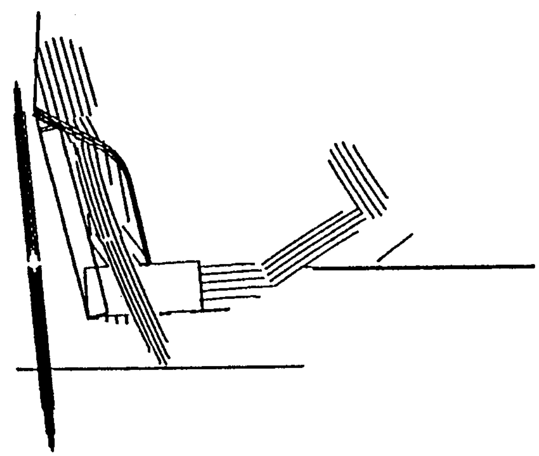
Time = 50 msec

91 05001 36

Occupant dynamic responses for Pulse 4 (contd)



SOM-LA

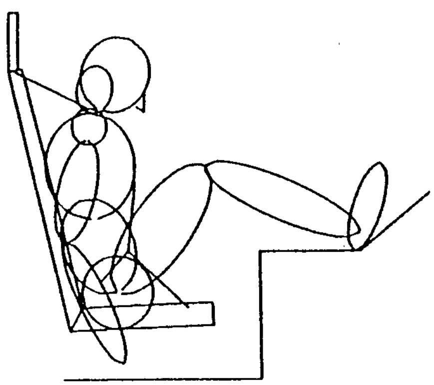


ATB model

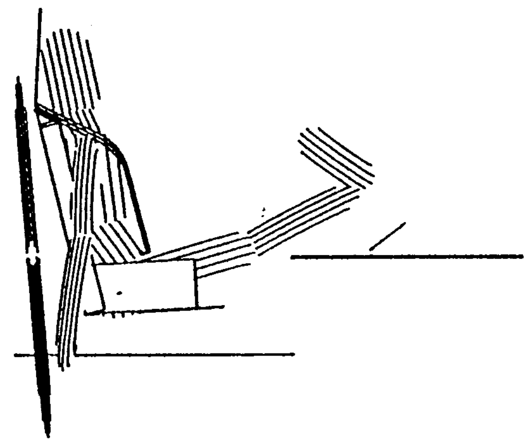
Time = 100 msec

91 05001 37

Occupant dynamic responses for Pulse 4 (contd)



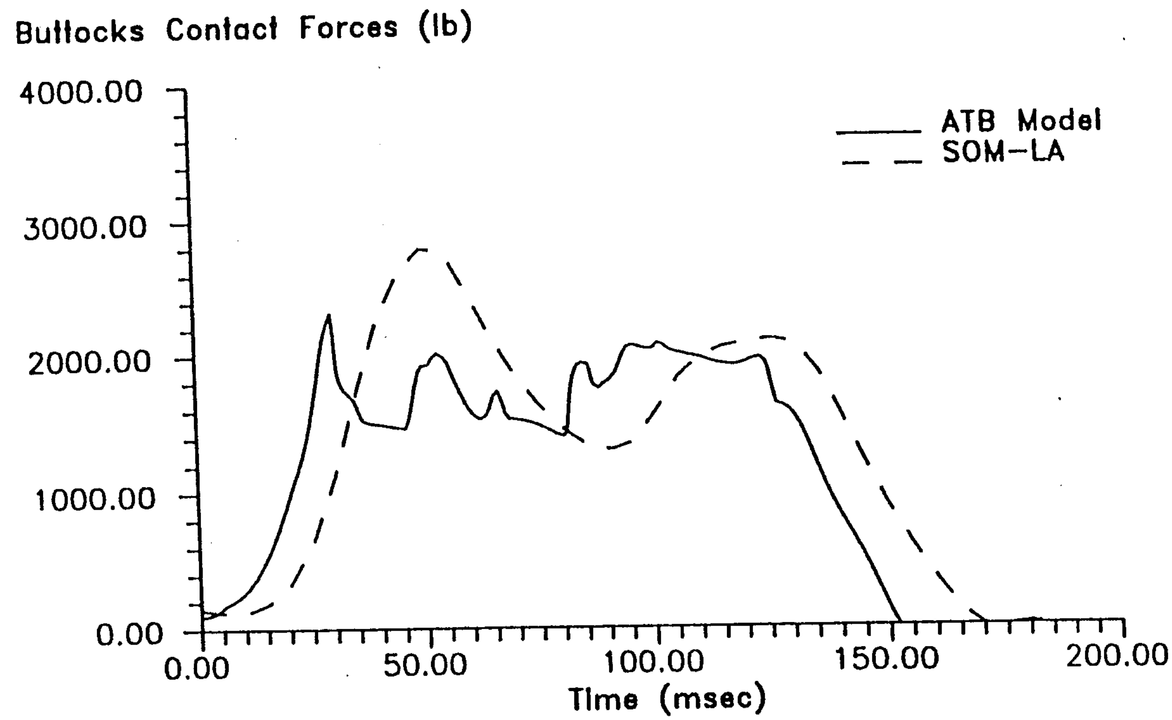
SOM-LA



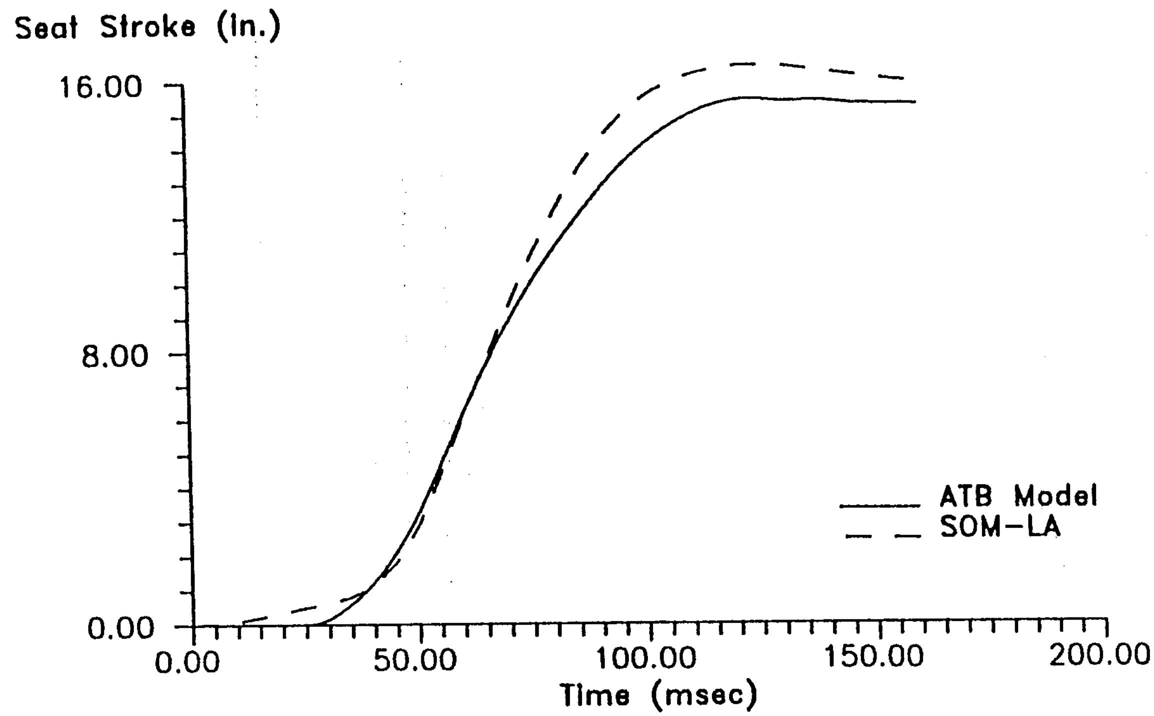
ATB model

Time = 140 msec

Buttocks/seat pan contact force time-histories for Pulse 4



Predicted seat strokes for Pulse 4



91 05001 39

Fuel Cell Retention Study

- ATB Model was used in support of Robertson Aviation for the analysis of an auxiliary fuel cell retention issue

- Question: What load is imposed on the fuel cell frame by the cell restraints?

95258- 10

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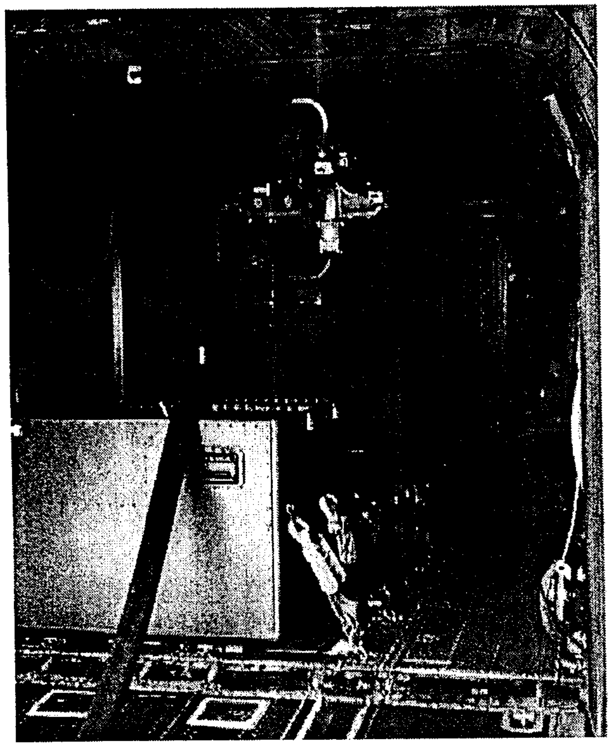
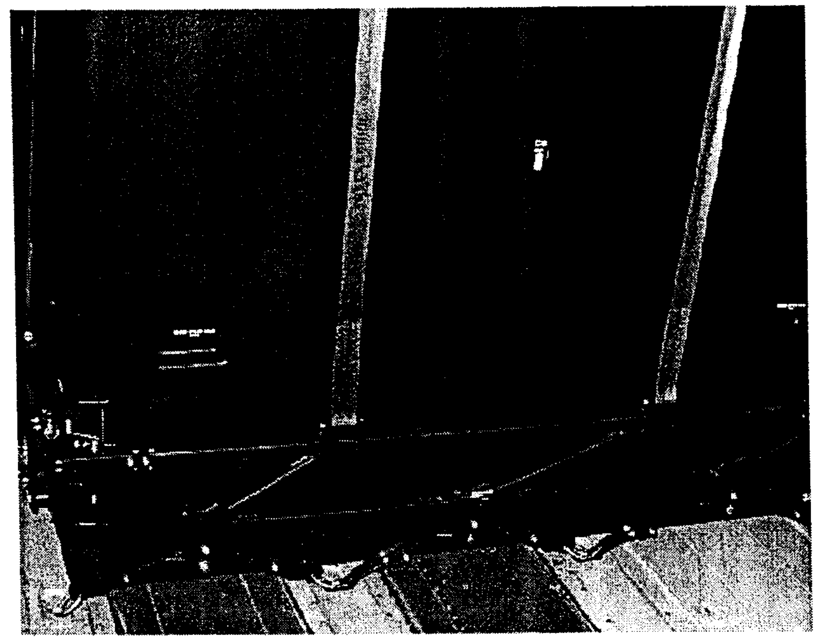
Fuel Cell Installed in Helicopter





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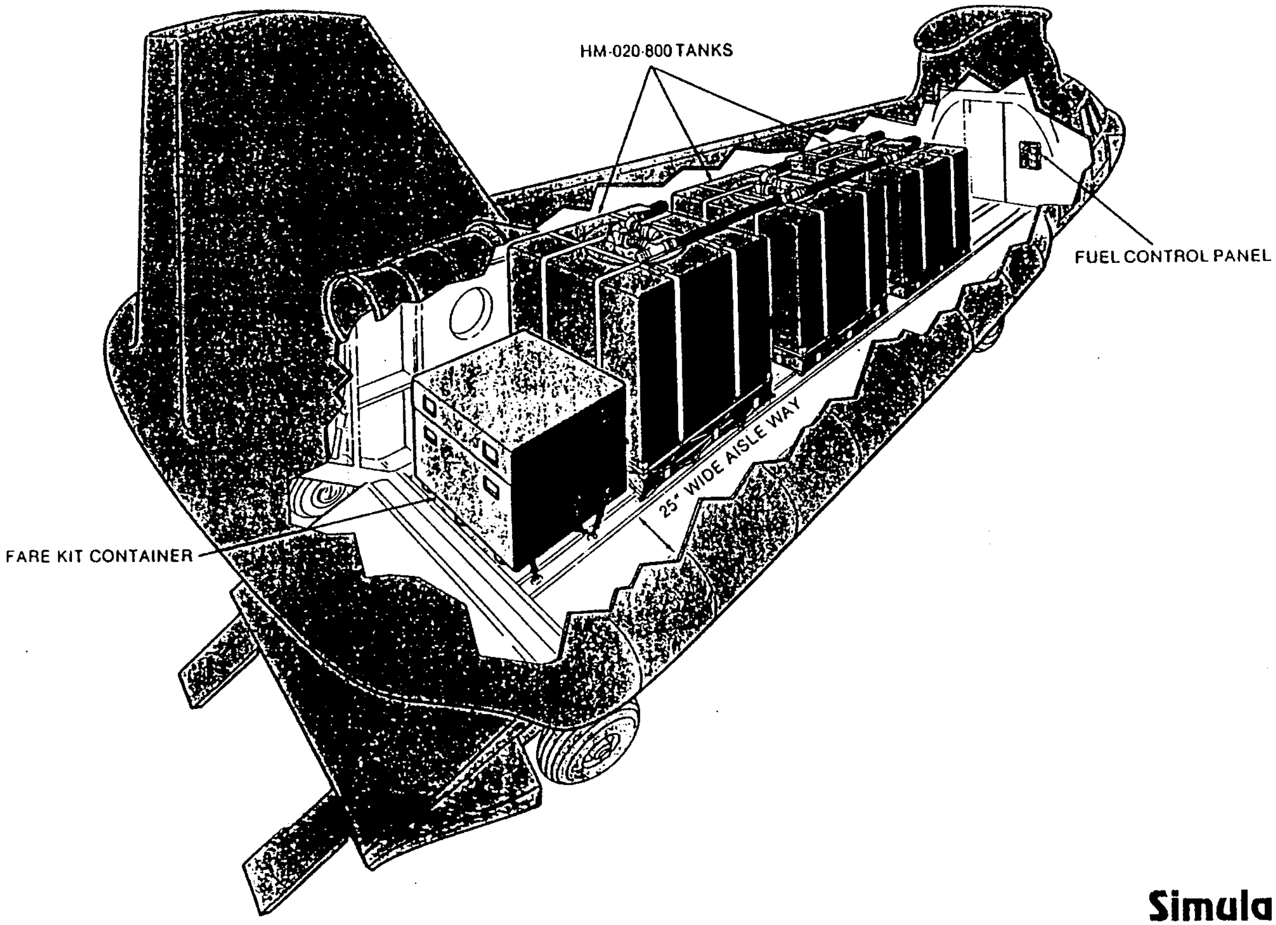
Fuel Cell Installation



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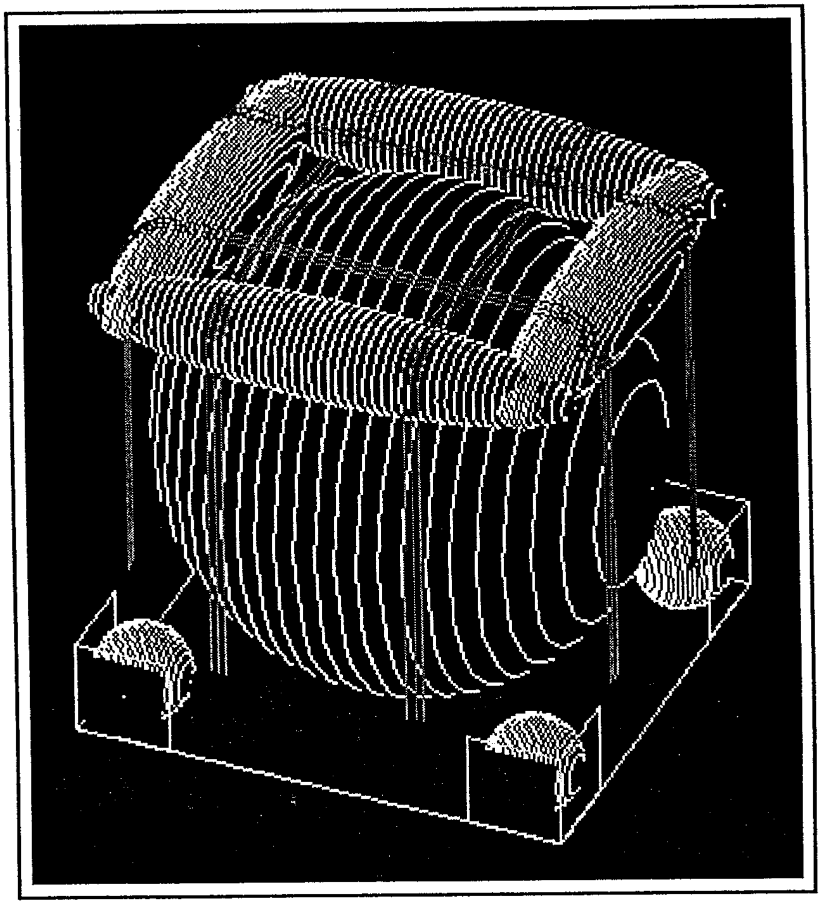
ATB Model of Fuel Cell



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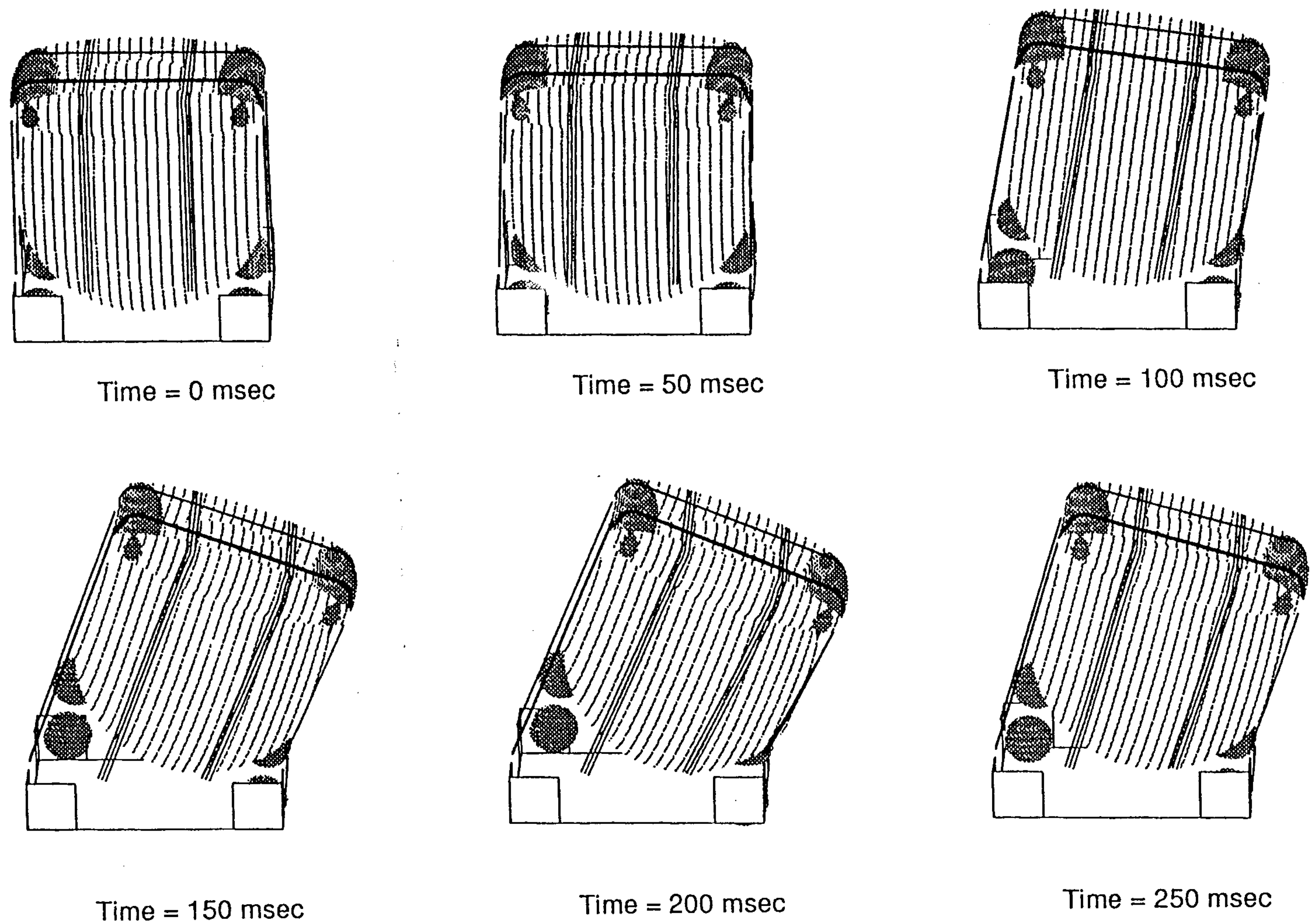
Predicted Fuel Cell Motions



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Results of Fuel Cell Analysis

- ATB results were used as a second opinion to other independent analyses
- ATB results generally agreed with independent results

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Concluding Remarks

- The ATB Model has a wide range of potential helicopter crashworthiness analysis applications
- Several such applications of the ATB model have been successfully demonstrated
- The general nature of the ATB Model allows adaptation to a wide variety of problems

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Recommended Development

- Improve/validate restraint models for a wide range of dynamic environments with varying degrees of restraint

- Increase the number of segments, planes, etc., to allow analysis of systems such as a three-place side-facing airplane seat

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Recommended Development

- Improve the user-friendliness of ATB and related programs <u>without</u> sacrificing its generality
- Augment GEBOD with additional manikin anthropometries
- Let's have a <u>single</u> ATB Model that meets the needs of all

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Proprietary Bug Fixes with Public Domain Software

- Company A
  - Finds and fixes bug
  - Corporate secret
  - Repeat the process

- Result: ATB is no longer standardized

- Company B
  - Gets bit by same bug
  - Repeat the process

- ATB suffers loss of confidence

- Companies A and B may both suffer

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Cost-Effectiveness (CE)

- Sharing code modifications and "wish lists" will improve CE for all users

- What is competitiveness and CE?
  - Having an ATB code no one else has after paying to modify the current ATB and every subsequent release
  - Being the most CE using a standard ATB code that has your "wish list" and mine included

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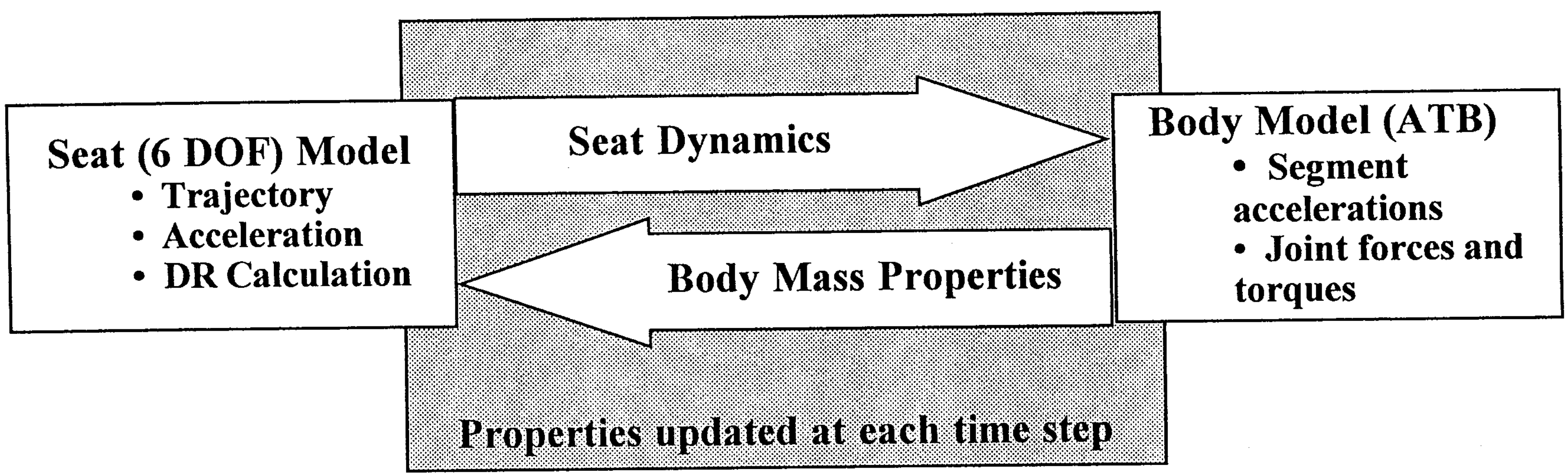
Ejection Seat and Occupant Interaction

Presented at ATB Users Colloquium
13-14 June 1995

John Quartuccio
Naval Air Warfare Center Aircraft Division
P.O. Box 5152
Warminster, PA 18974-0591
(215)441-7602

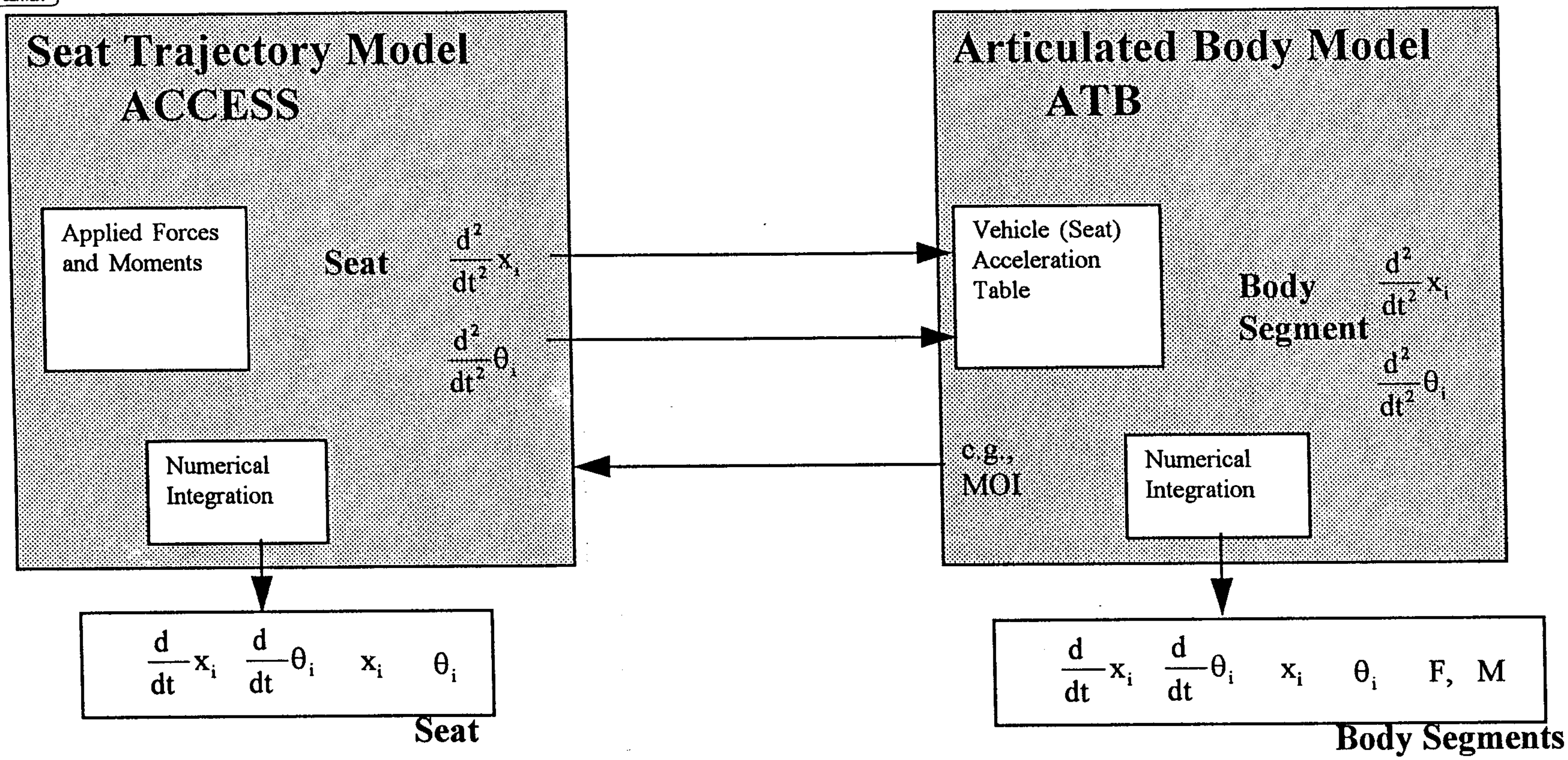
- **Dynamic Mass Property Analysis**
  - Combining the 6DOF model with the ATB model
  - Enables injury projection throughout the escape sequence



Analysis Needs

- Variation of mass properties during the ejection sequence
- Body segment motion
- Joint forces and moments

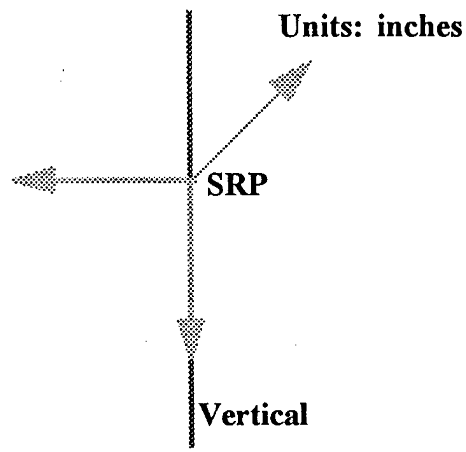
Model Structure



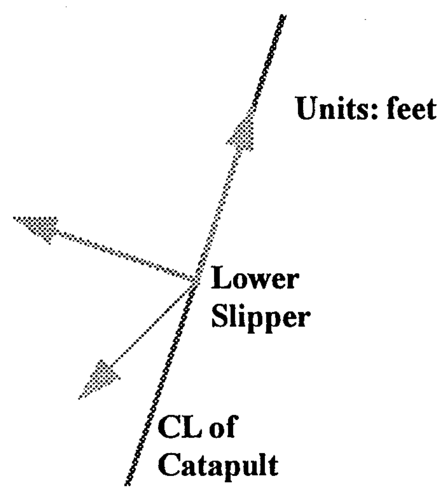
Applied Moments and Forces Include
- Catapult Loading
- Rocket Loading
- Aerodynamic Loading
- Stabilization Devices
- Recovery Loading

Body Segments Include
- Lower Torso
- Torso
- Upper Torso
- Neck
- Head
- Upper Arms
- Lower Arms
- Upper Legs
- Lower Legs
- Feet

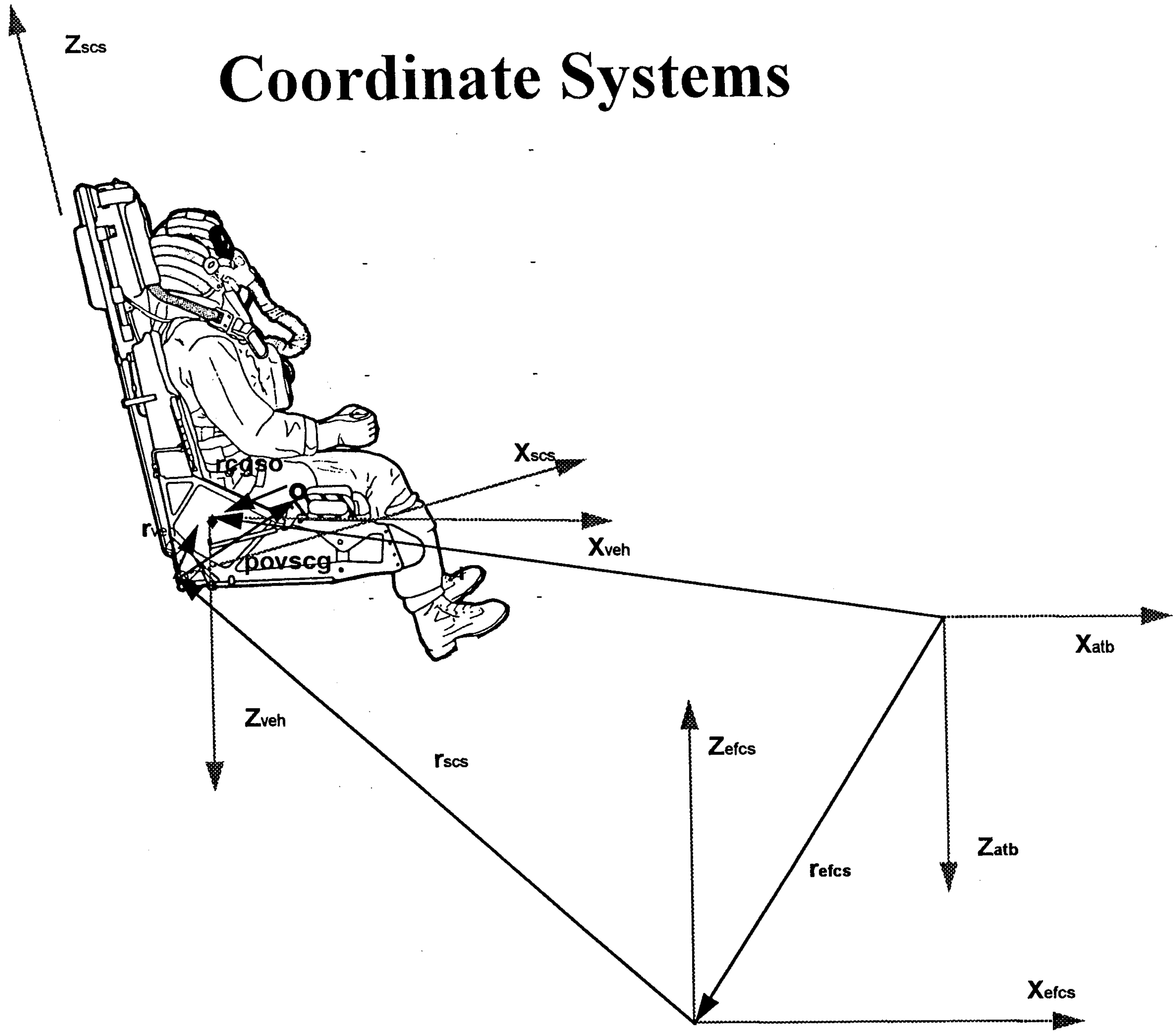
Articulated Total Body (ATB) Model Coordinate System



Seat Coordinate System (SCS)



Coordinate Systems

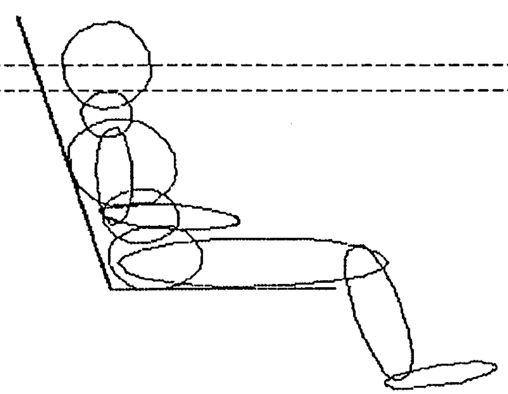


Mass Property Calculations

Occupant Alone

seg	weight (lb)	x (in)	y (in)	z (in)	Ixx (inlbs^2)	Iyy (inlbs^2)	Izz (inlbs^2)	Ixy (inlbs^2)	Iyz (inlbs^2)	Ixz (inlbs^2)
LT	18.770	3.791	0.000	-3.381	0.657	0.386	0.586	0.000	0.000	-0.017
CT	3.720	2.579	0.000	-8.633	0.052	0.027	0.068	0.000	0.000	0.004
UT	20.170	1.168	0.000	-14.742	0.664	0.569	0.479	0.000	0.000	-0.045
N	1.700	-0.105	0.000	-20.937	0.010	0.010	0.007	0.000	0.000	0.000
H	8.080	-0.105	0.000	-26.837	0.147	0.167	0.086	0.000	0.000	0.000
RUL	13.570	11.509	3.220	-2.913	0.115	0.866	0.866	0.000	0.000	0.000
RLL	5.000	21.553	3.220	3.167	0.181	0.189	0.029	0.000	0.000	-0.037
RF	1.110	25.497	3.220	10.884	0.003	0.015	0.015	0.000	0.000	0.003
LUL	13.570	11.509	-3.220	-2.913	0.115	0.866	0.866	0.000	0.000	0.000
LLL	5.000	21.553	-3.220	3.167	0.181	0.189	0.029	0.000	0.000	-0.037
LF	1.110	25.497	-3.220	10.884	0.003	0.015	0.015	0.000	0.000	0.003
RUA	1.830	0.457	5.380	-13.361	0.035	0.035	0.004	0.000	0.000	0.000
RLA	2.270	4.930	0.907	-8.518	0.041	0.041	0.076	0.036	0.004	-0.004
LUA	1.830	0.457	-5.380	-13.361	0.035	0.035	0.004	0.000	0.000	0.000
LLA	2.270	4.930	-0.907	-8.518	0.041	0.041	0.076	-0.036	-0.004	-0.004
Total	100.000	7.118	0.000	-7.562	22.521	35.431	17.622	0.000	0.000	-12.864

cg(SRP):=>	9.433	0.000	4.345	(in) Parallel to the catapult, origin at SRP
cg(SCS):=>	1.102	0.000	1.213	(ft) Parallel to catapult, origin at lower slipper
Moments:=>	2.564	0.000	0.629	(slug-ft^2)
of :=>	0.000	2.953	0.000	
Inertia:=>	0.629	0.000	0.781	

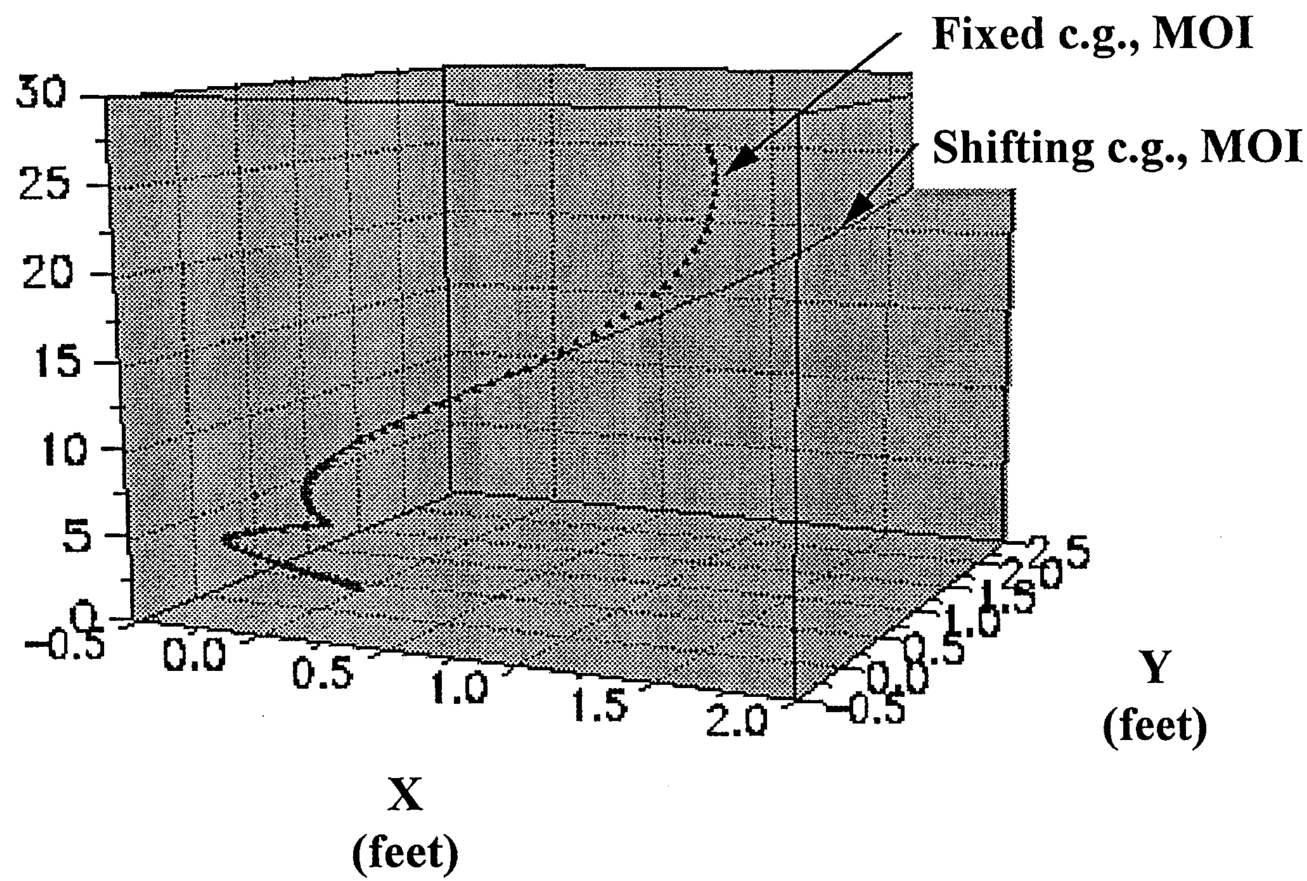


Process Validation

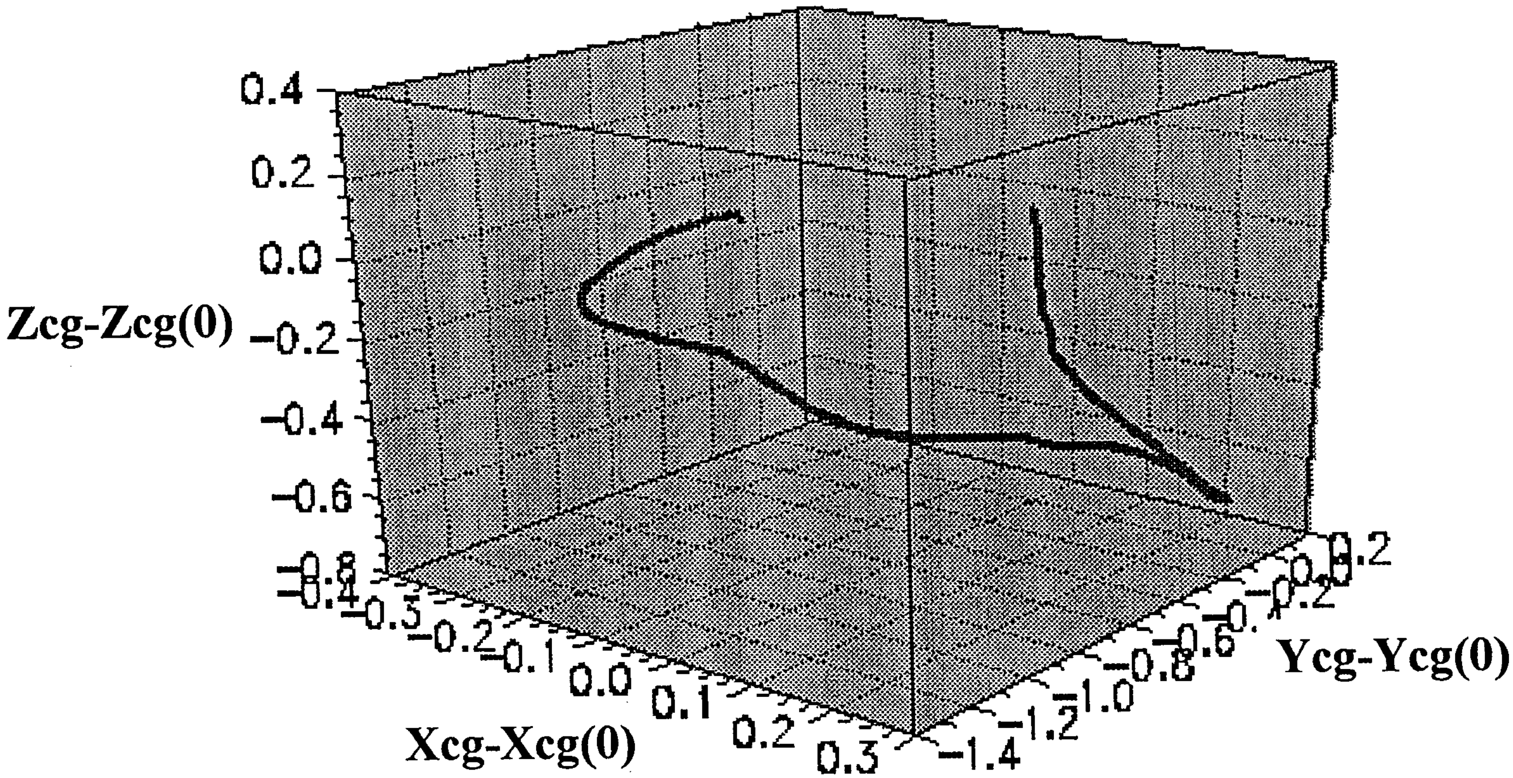
- **Software Modifications**
  - Resulting vehicle accelerations were input as DYNAMAN input
  - Produced nearly identical output
- **Implementation**
  - Integrators for both the ATB and ACCESS produced nearly identical position and DCM

```
time =   0.4000

Seat Displacement:
     (ATB):=>        -11.015      3.857      13.448  (ft)
  (ACCESS):=>        -11.02       3.85       13.41   (ft)

Direction Cosine Matrices:
                 ----------------------------------------
Seat DCM  :=>           0.551      0.630       0.548
  (ATB)   :=>          -0.651      0.735      -0.191
    D     :=>          -0.523     -0.251       0.815
                 ----------------------------------------
Seat DCM  :=>           0.706     -0.678      -0.203
        :=>          0.651      0.735      -0.191
 B^T *D^T a :=>         0.279      0.003       0.960
                 ----------------------------------------
Seat DCM  :=>           0.707     -0.678      -0.198
(ACCESS)  :=>           0.652      0.735      -0.189
  dcmse   :=>           0.274      0.004       0.962
                 ----------------------------------------
```

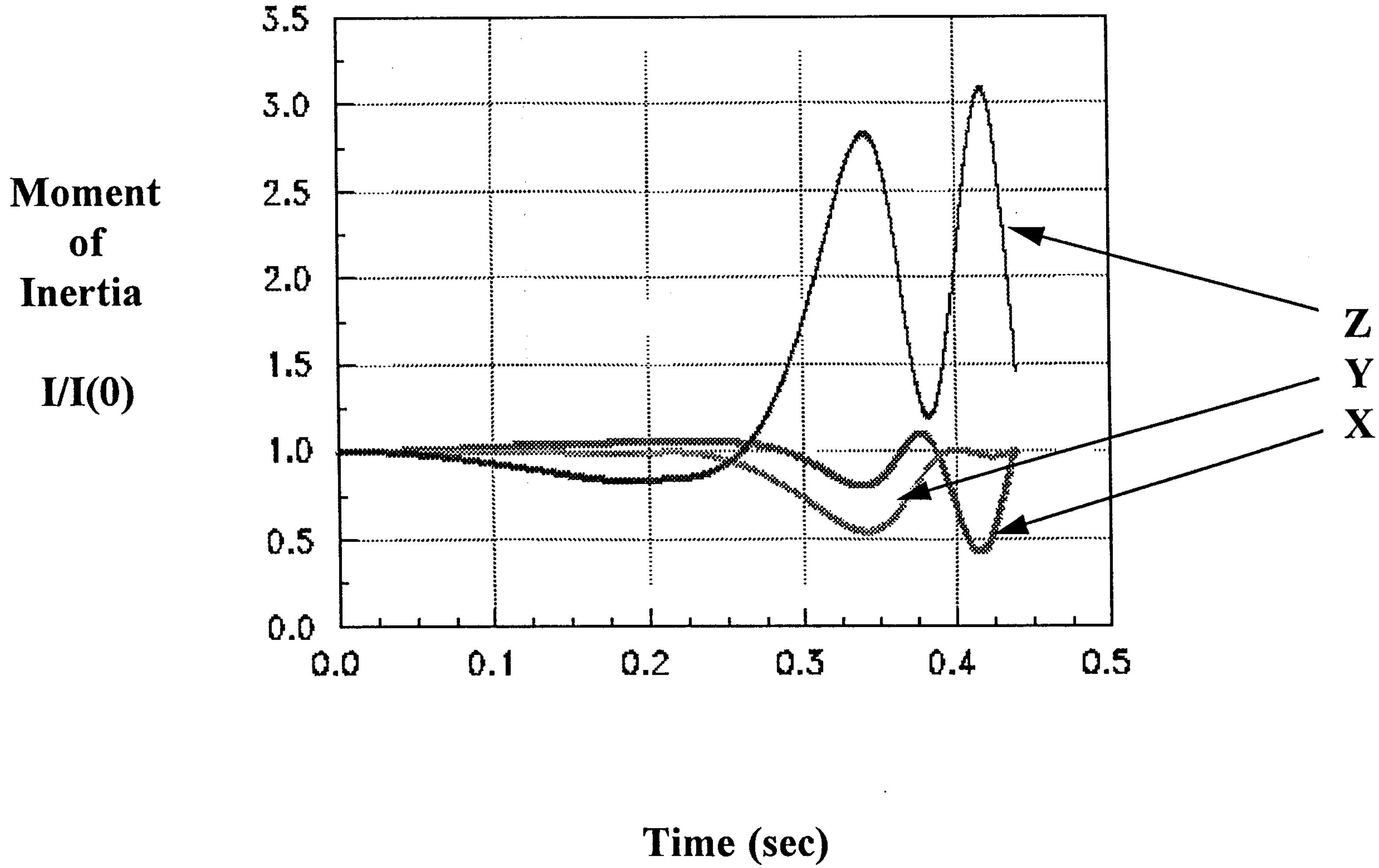
Seat Trajectory Relative to Earth



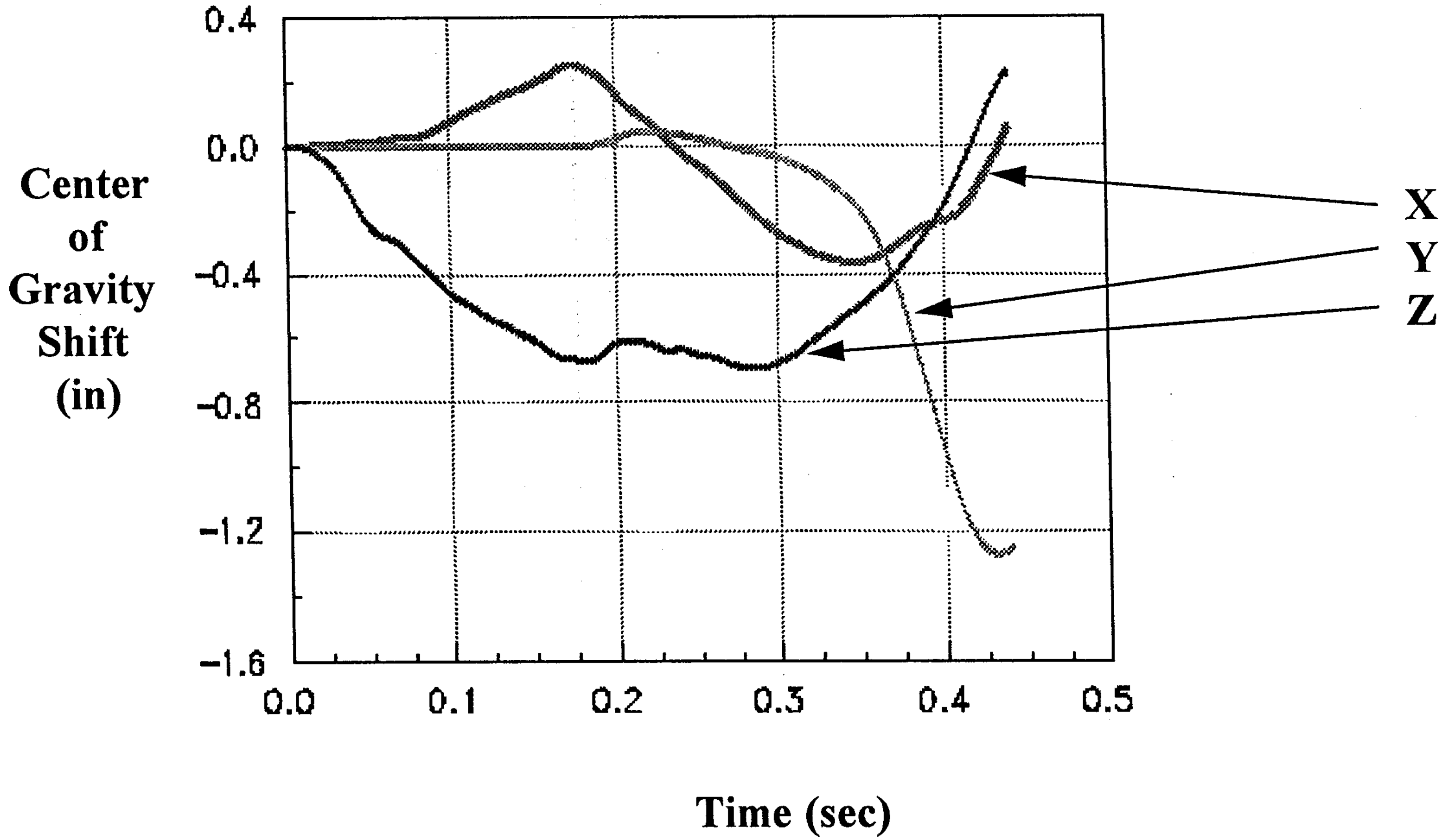
Center of Gravity Trajectory Relative to Seat



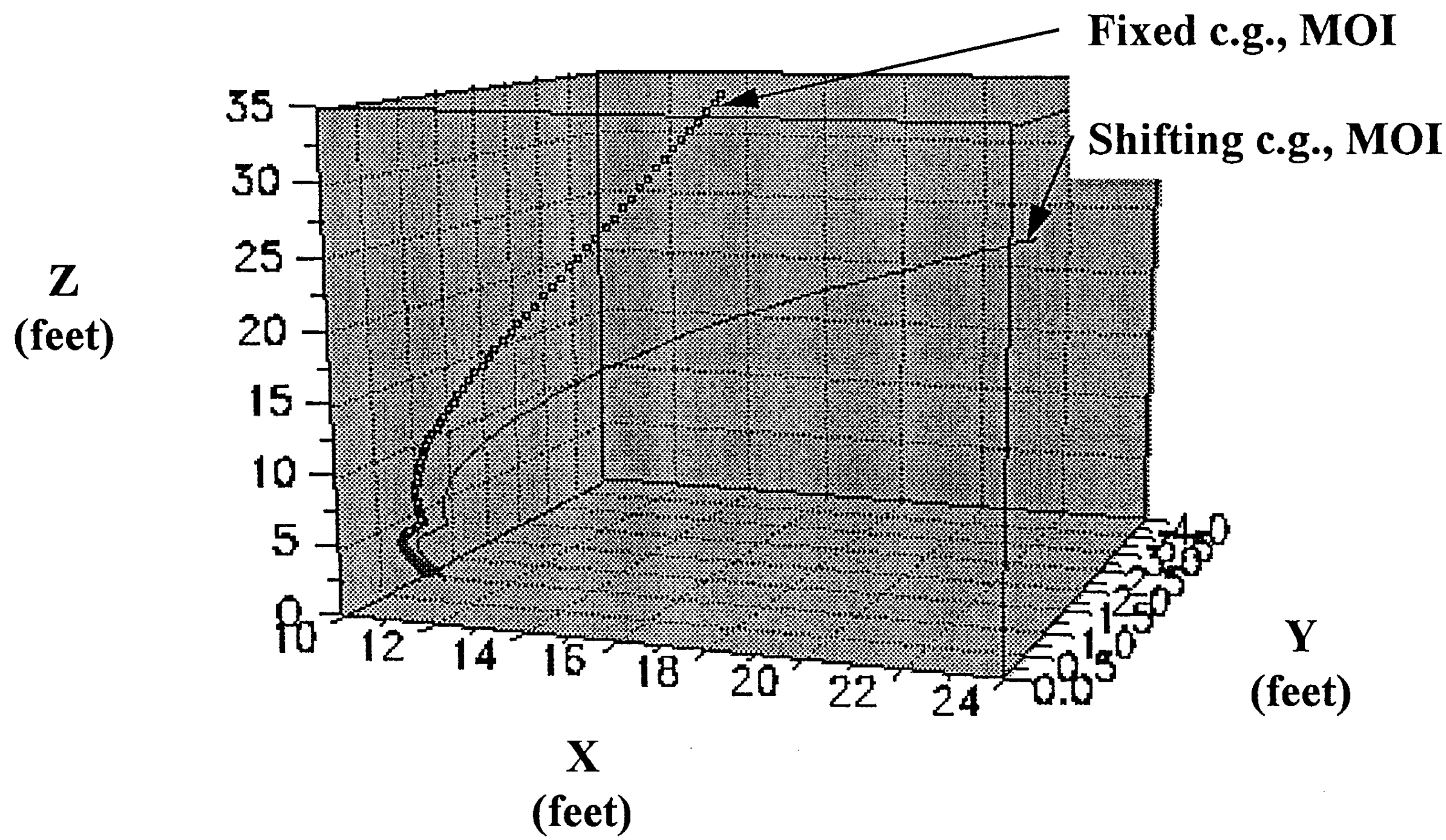
Moments of Inertia Variation



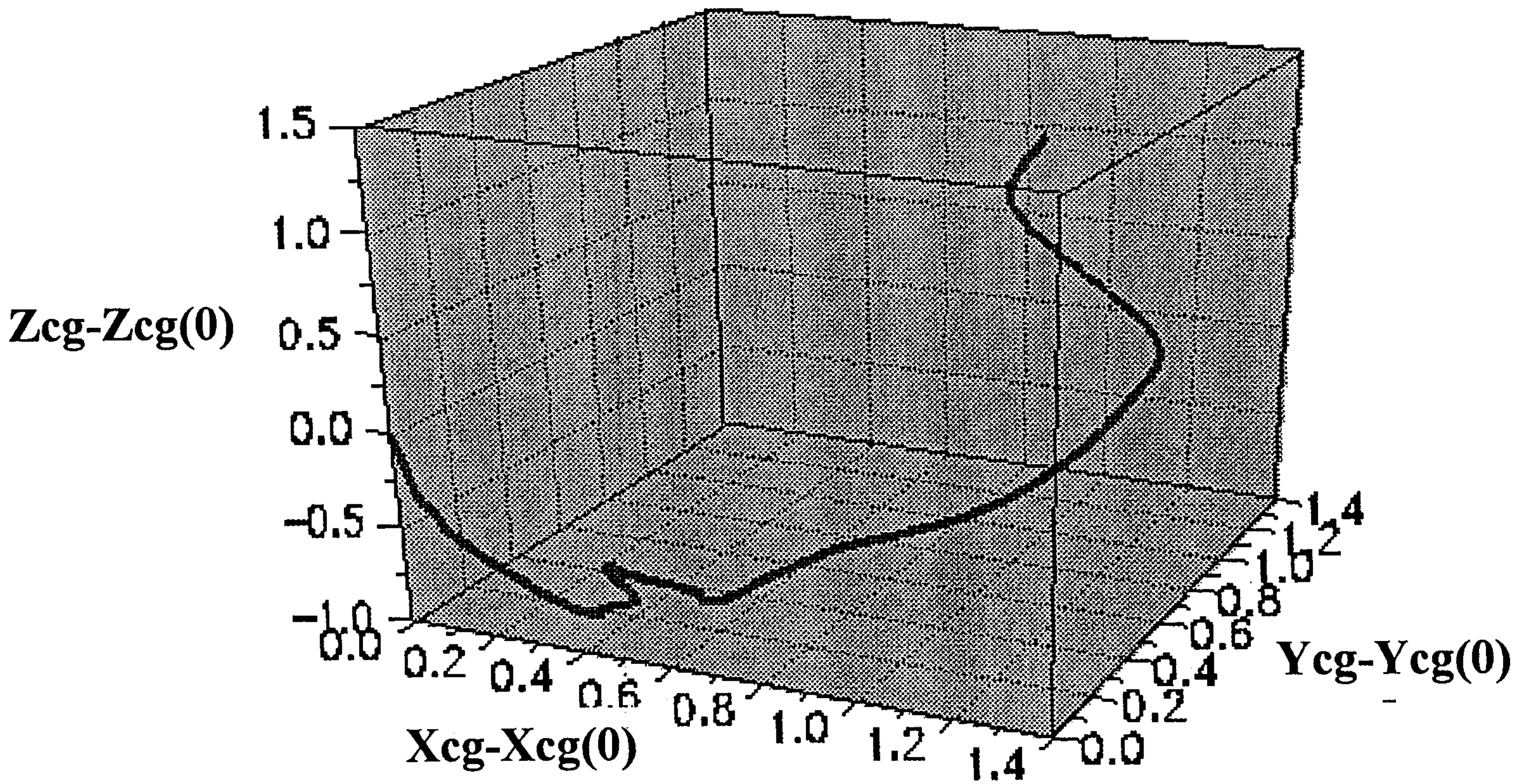
C.G. Trajectory Relative to Seat



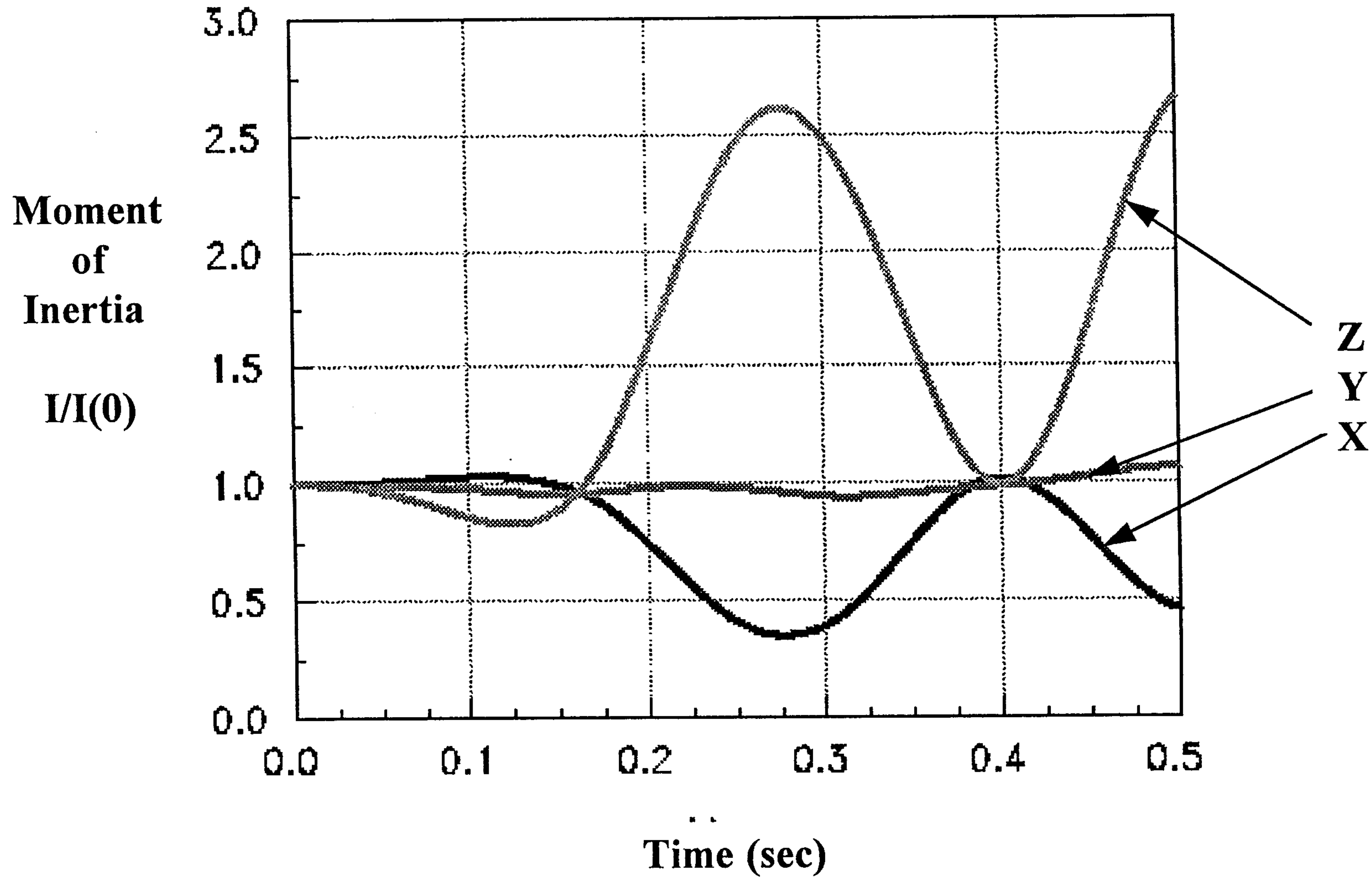
Seat Trajectory Relative to Earth



Center of Gravity Trajectory Relative to Seat



Moments of Inertia Variation



Findings

- ATB works well as an internal computation loop for system analysis

- The approach permits the use of an independently validated body input model and a validated system model

- The final analysis enables a more complete solution

Introduction of Deformable Segments in The ATB Model

1- Human and Manikin Neck Models

by

Hashem Ashrafiuon
Associate Professor

and

Robert Colbert
Graduate Assistant

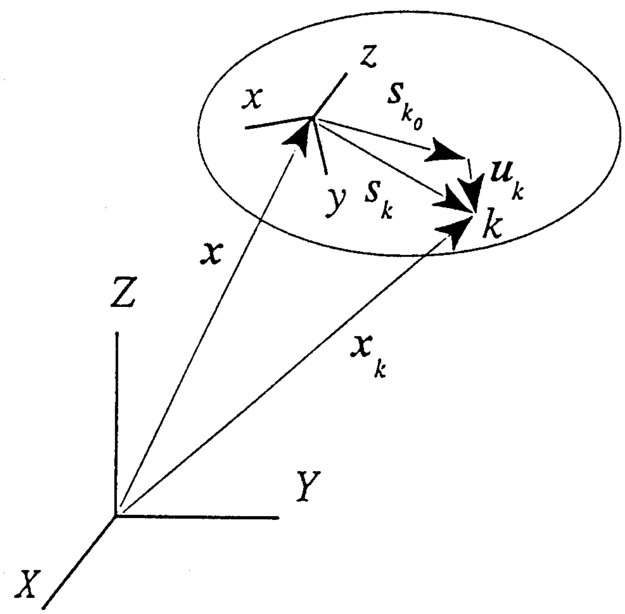
Mechanical Engineering Department
Villanova University
Villanova, Pennsylvania

OBJECTIVE

1- To accurately model segments with significant structural deformation in addition to the rigid body motion.

2- To predict head/neck motion more accurately.

3- To help design a more realistic manikin neck.



Kinematics of a deformable body

APPROACH

* Revise ATB mathematical formulation to incorporate vibrational deformation modes of individual segments in addition to the rigid body modes.

* Develop finite element model(s) of the deformable segment(s) and determine the relevant natural frequencies and mode shapes.

* Create a data file for each deformable segments containing nodal positions, natural frequencies, and mode shapes.

* Revise the ATB ".ain" (input) file to accept and read the deformable segment data.

LIMITATIONS:

* Plastic (permanent) deformation can not be modeled.
* Rotational deformation must be less than 1 rad.

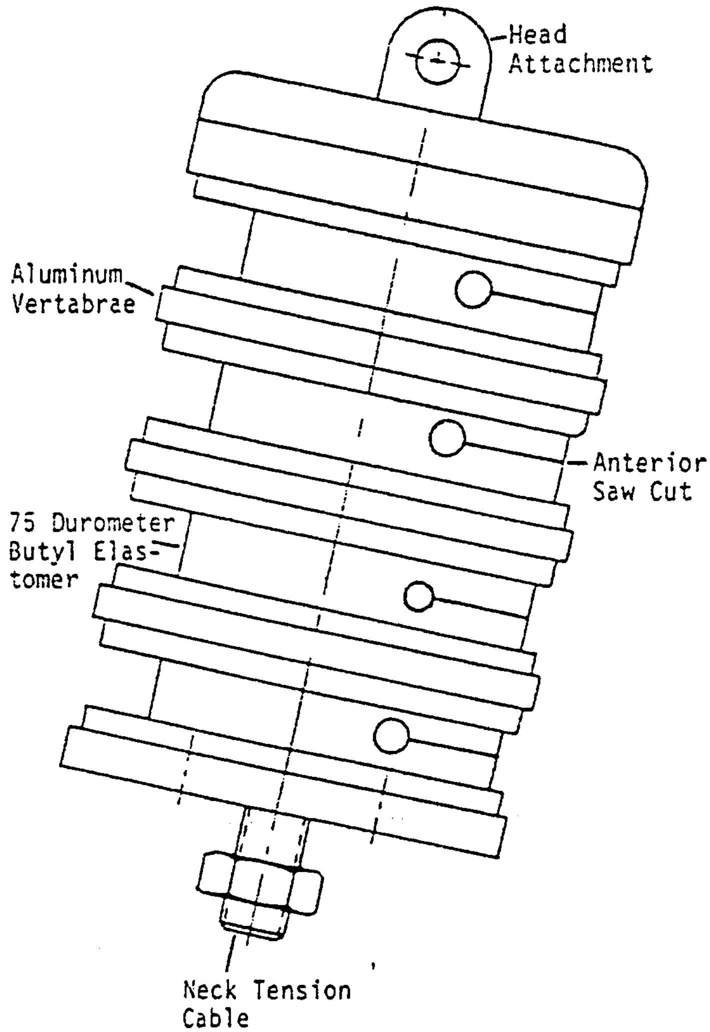
INPUT DATA

* There are two postprocessors written for ANSYS and NIKE3D to create the additional input file(s) needed for the ATB.

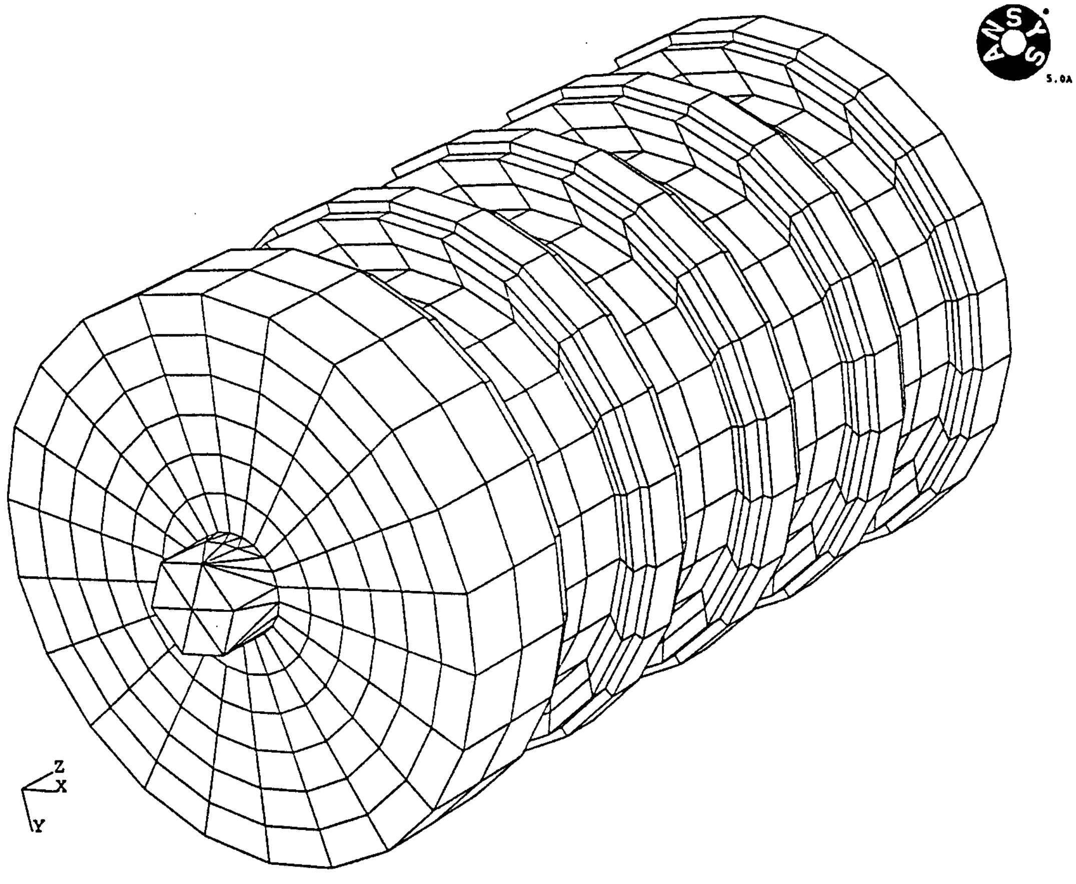
* Minimum additional data must be entered in the ATB ".ain" file. These data include:

  - No. of deformable bodies (segments)
  - ATB segment no. of the deformable body
  - Deformable body data file name
  - Modal damping ratios (estimated)
  - Initial modal positions and velocities (usually 0)
  - Joint attachment node numbers

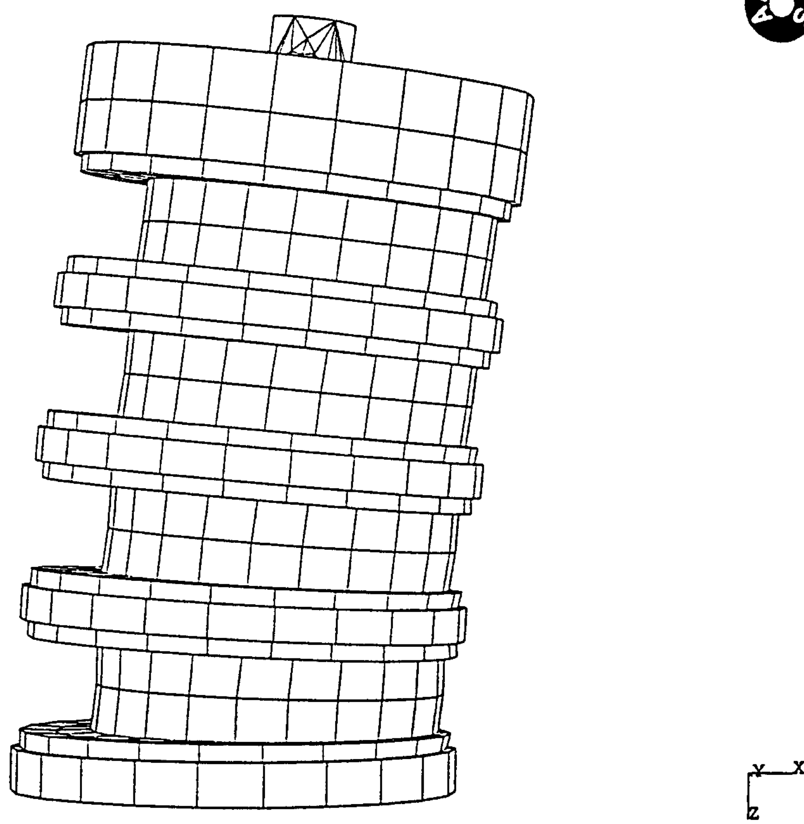
NOTE: The revised ATB computer program is compatible with the previous ATB programs for rigid body modeling.



Hybrid III manikin neck

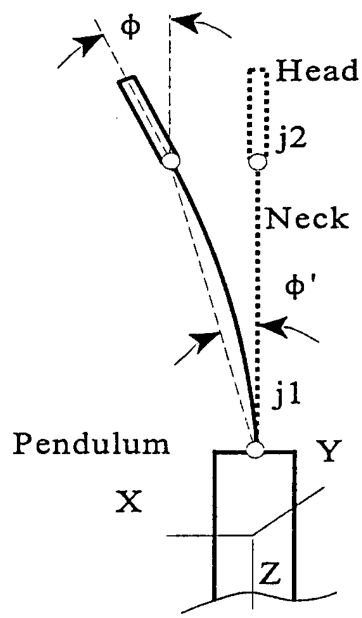


Hybrid III finite element mesh

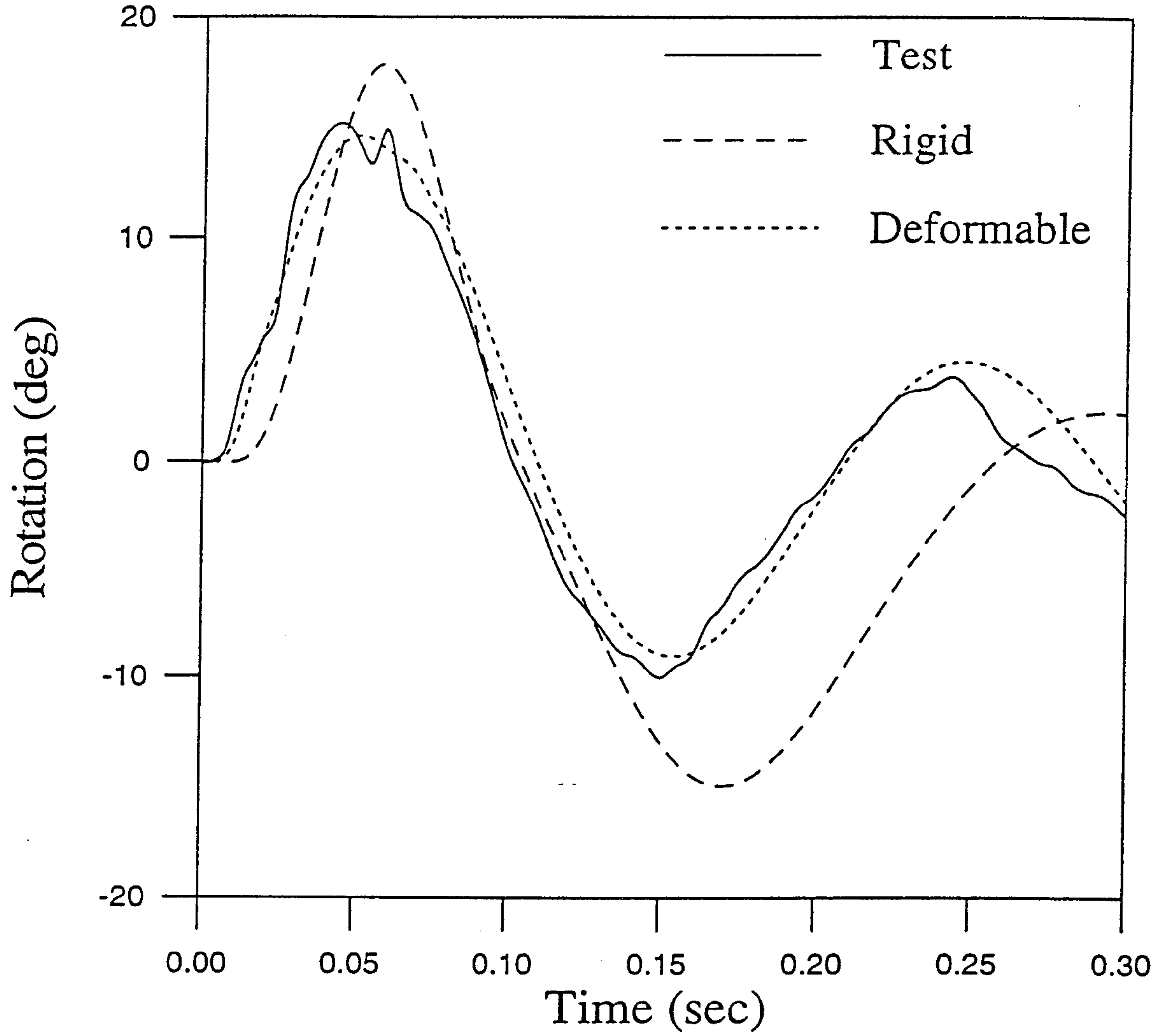


Hybrid III first mode shape (36.1 Hz)

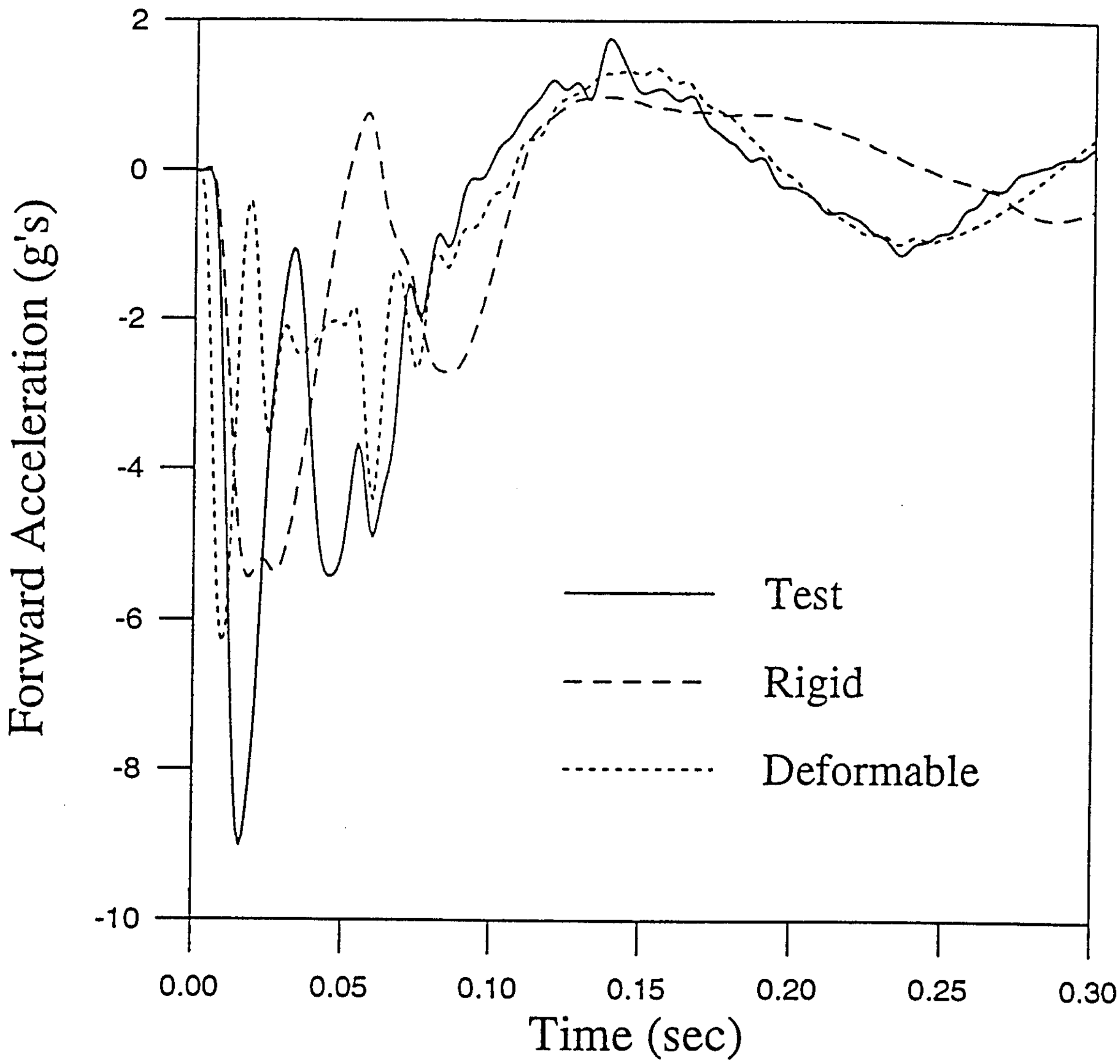
HEAD/NECK PENDULUM TEST



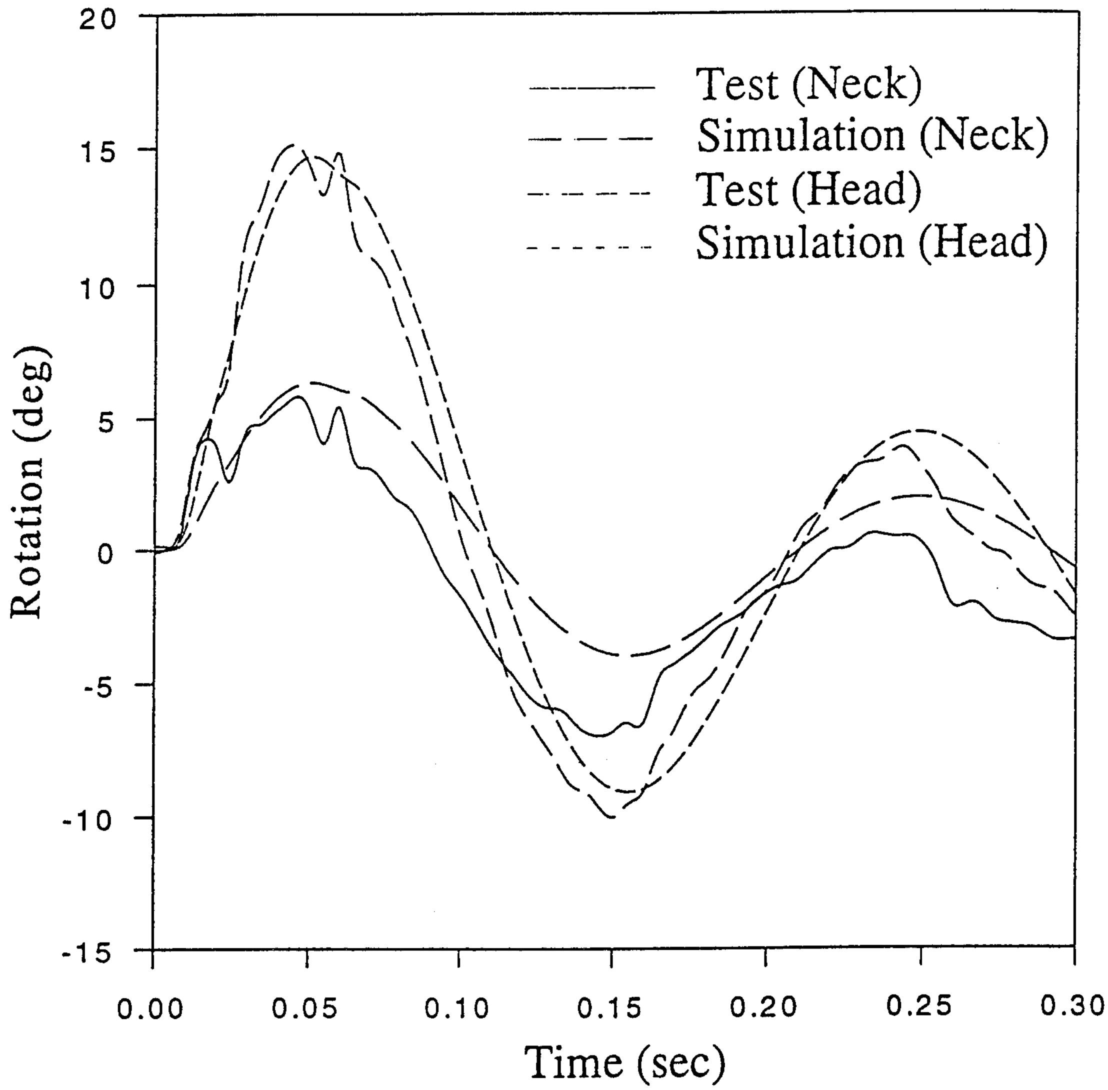
Hybrid III Head/Neck Pendulum Test Model



Comparison of Hybrid III head rotations in HNP 20° flexion test



Comparison of Hybrid III head rotations in HNP 20° flexion test



Hybrid III rotations in HNP 20⁰ flexion test

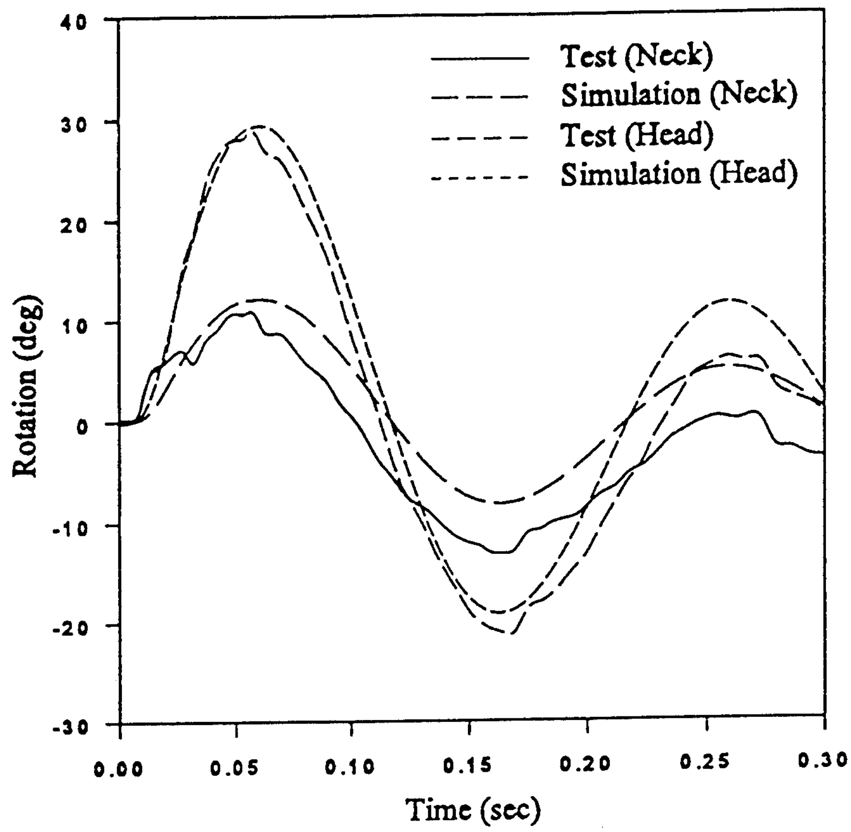
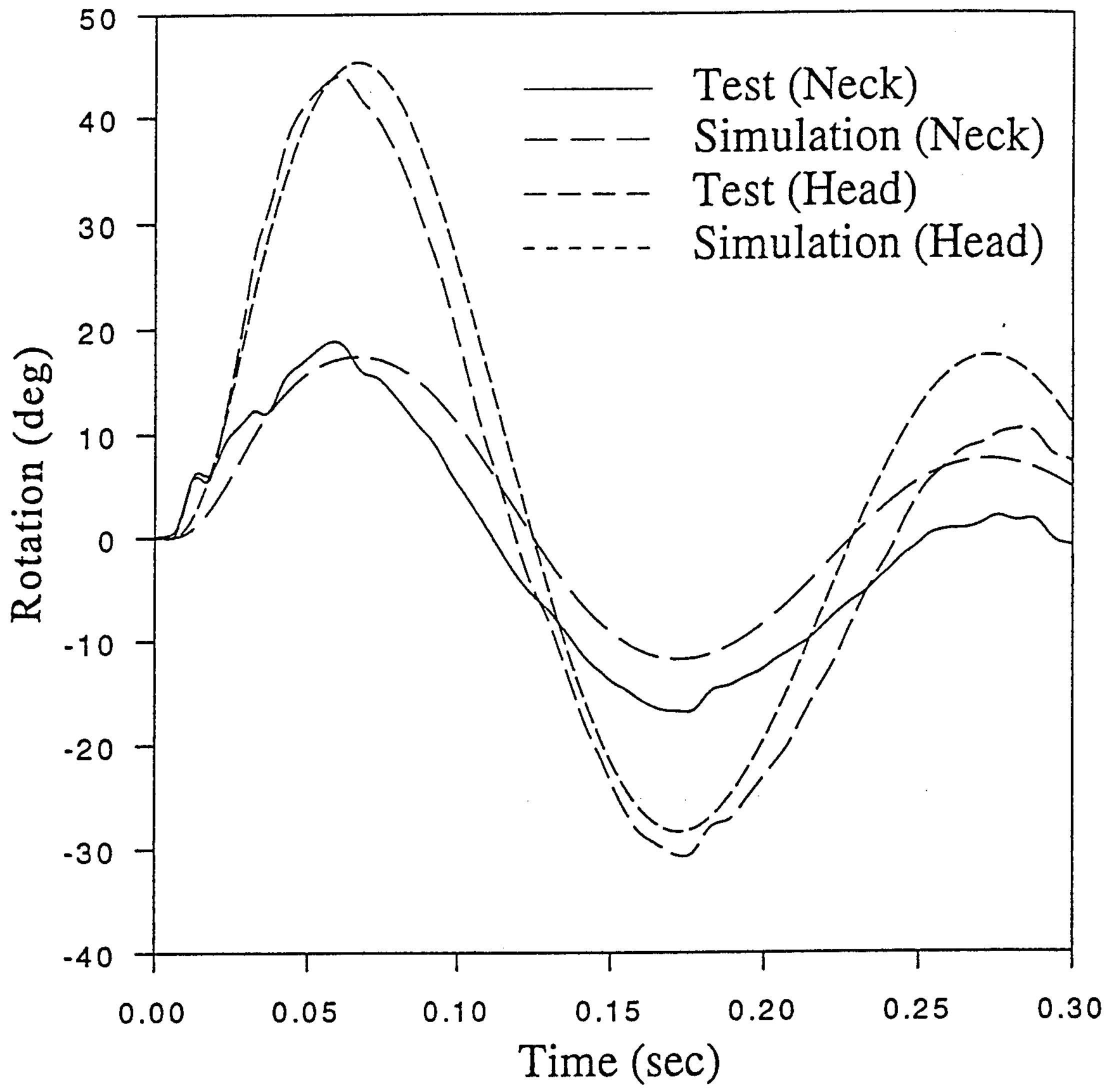


Figure 6. Hybrid III Rotations in HNP 40^0 Flexion Test



Hybrid III rotations in HNP 60⁰ flexion test

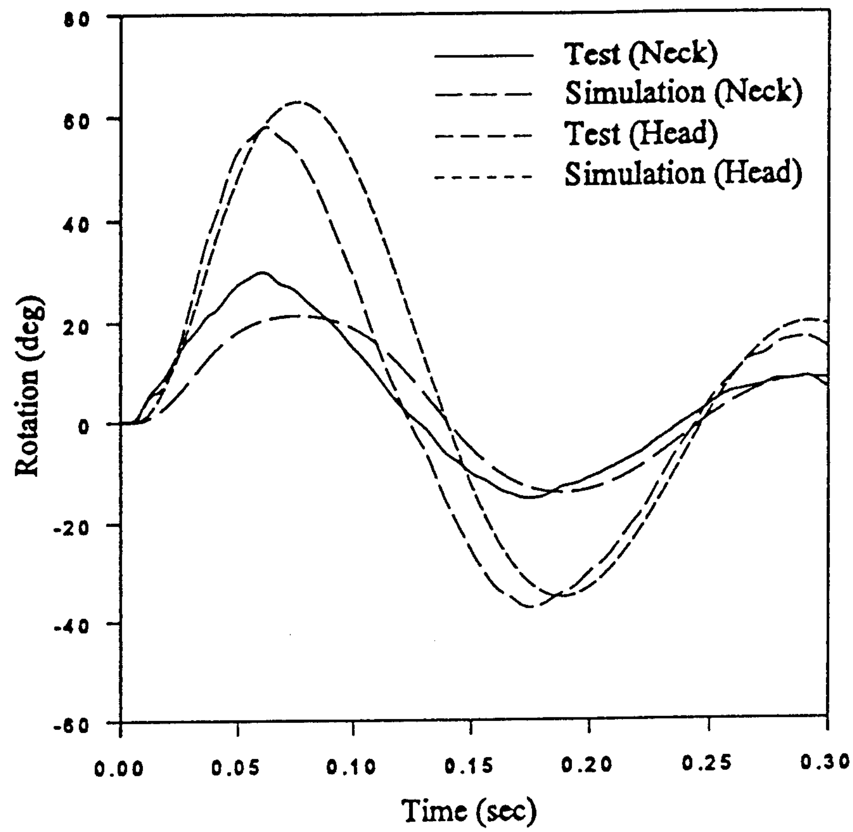
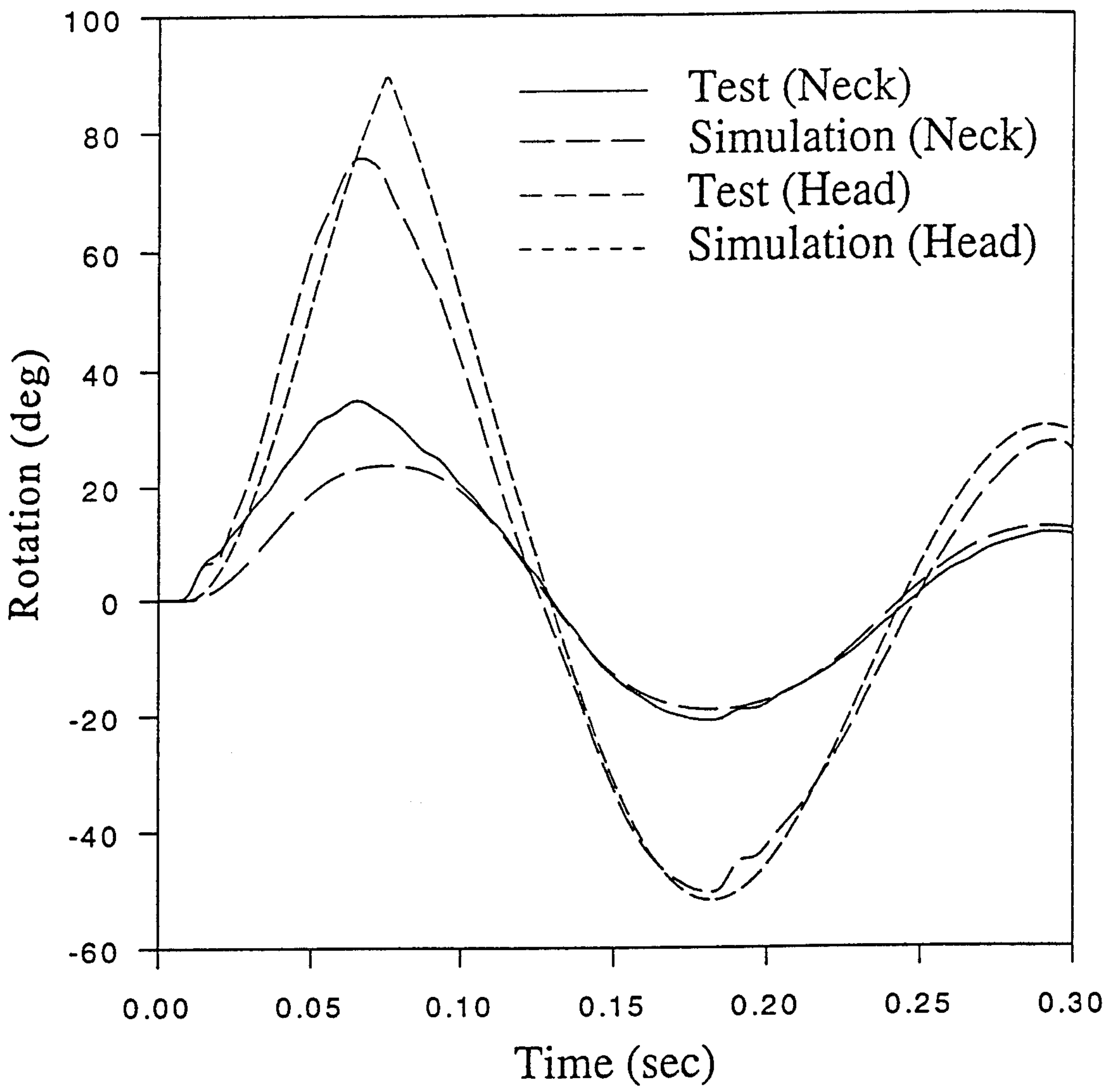
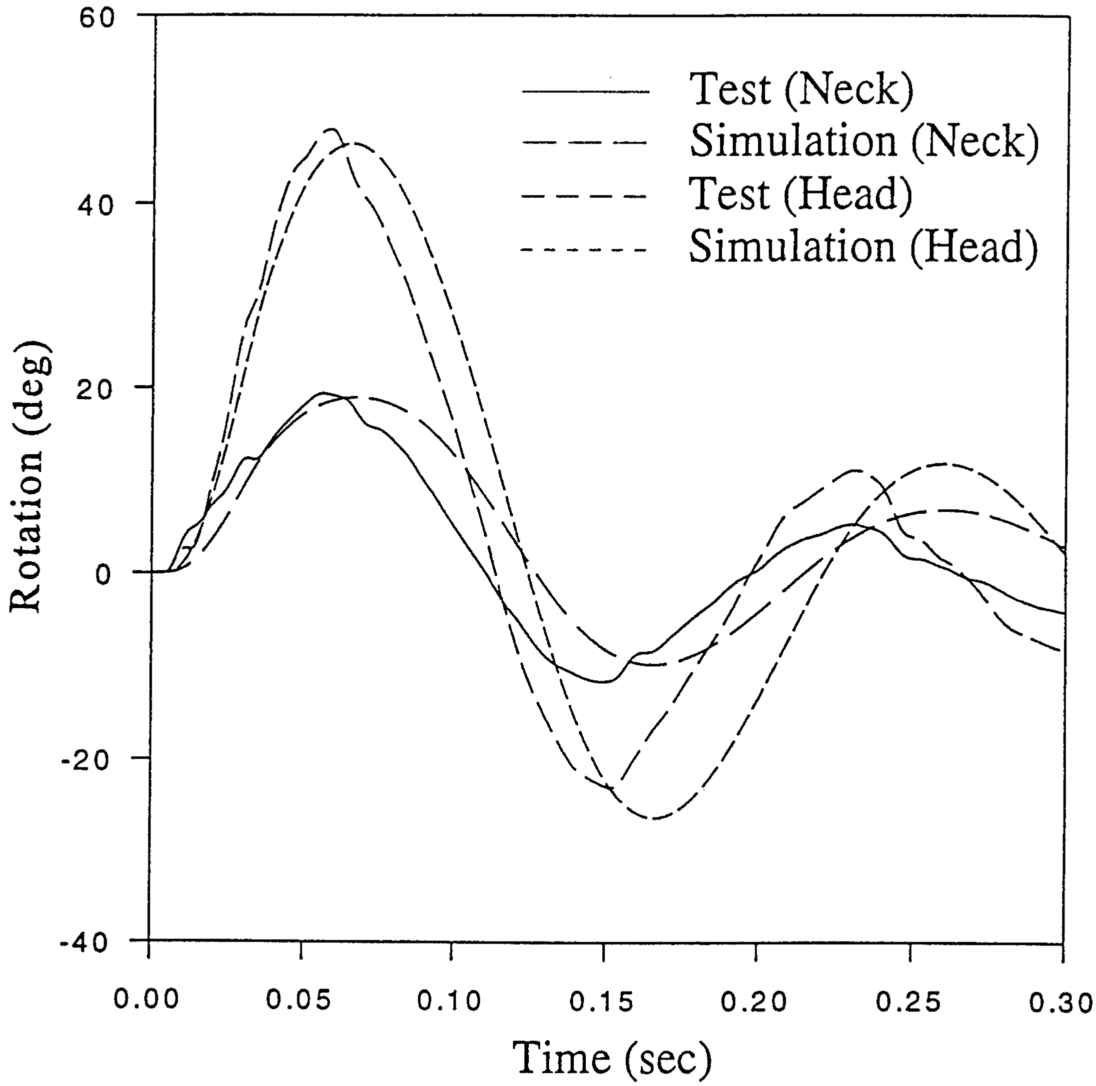


Figure 8. Hybrid III Rotations in HNP 80^0 Flexion Test



Hybrid III rotations in HNP 120^0 flexion test



Hybrid III rotations in HNP 65^0 lateral test

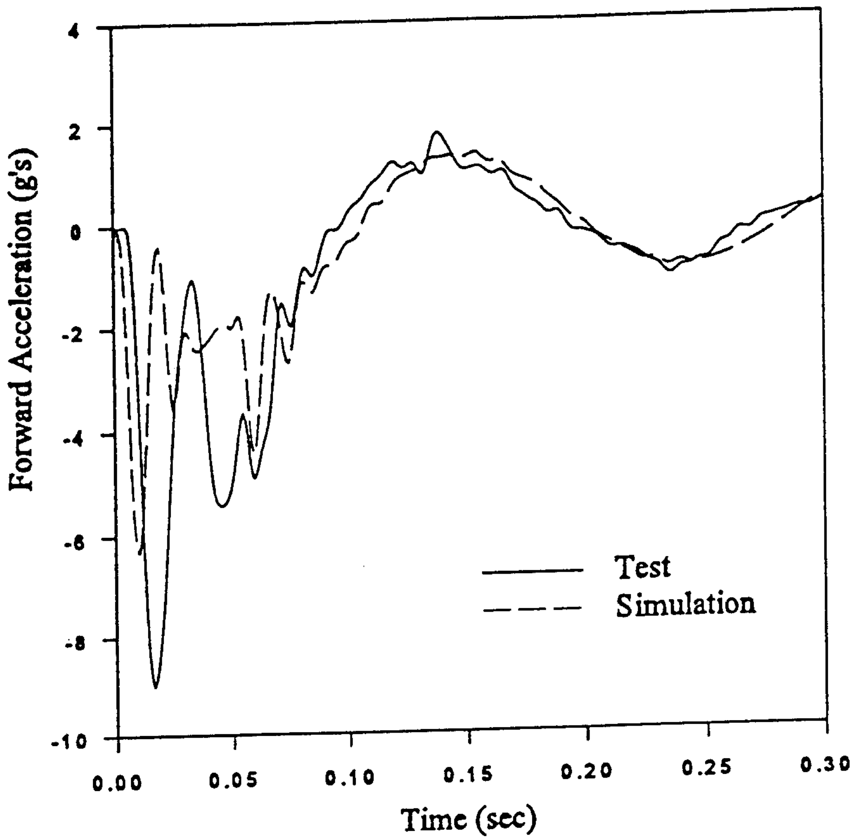
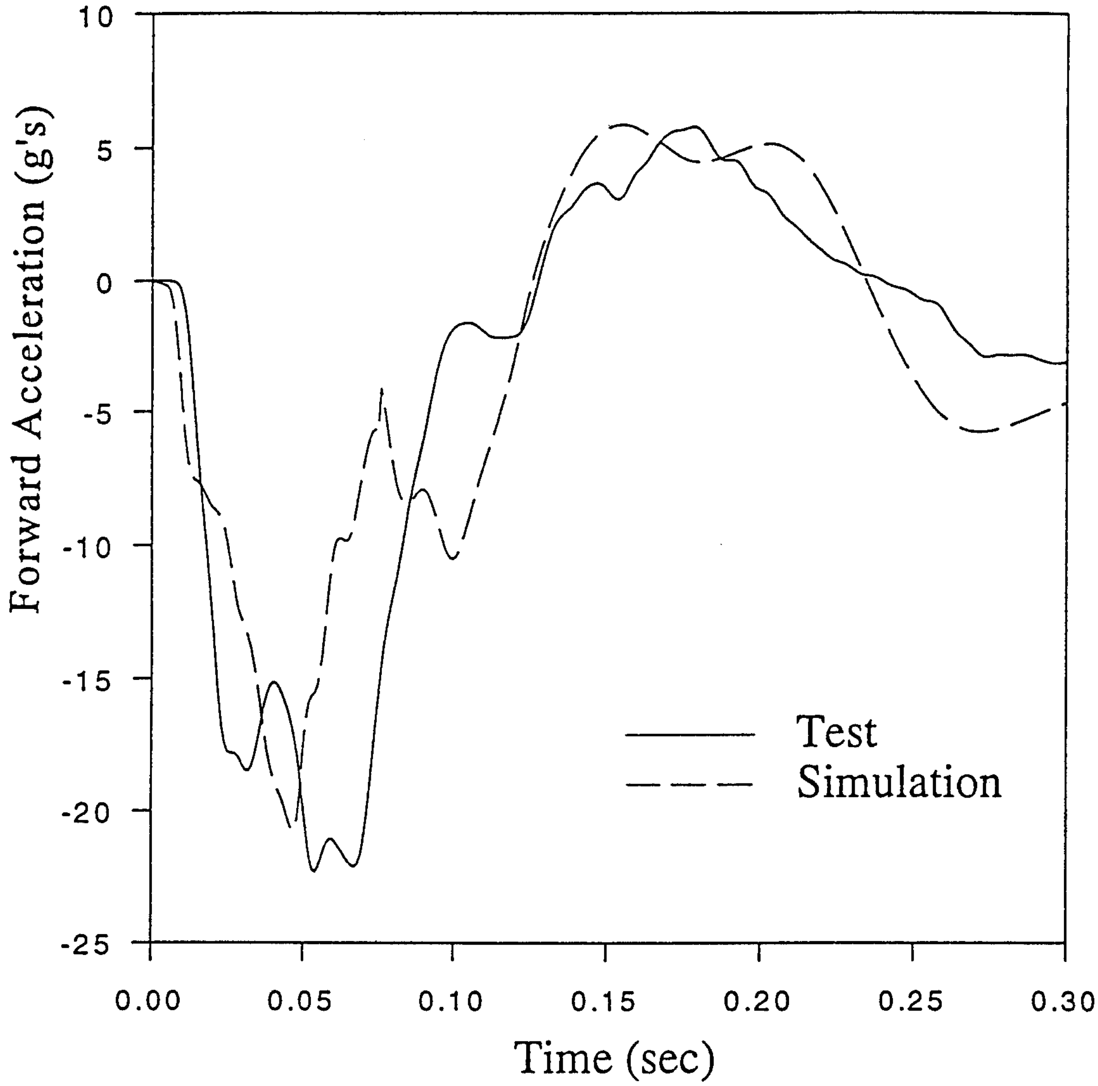
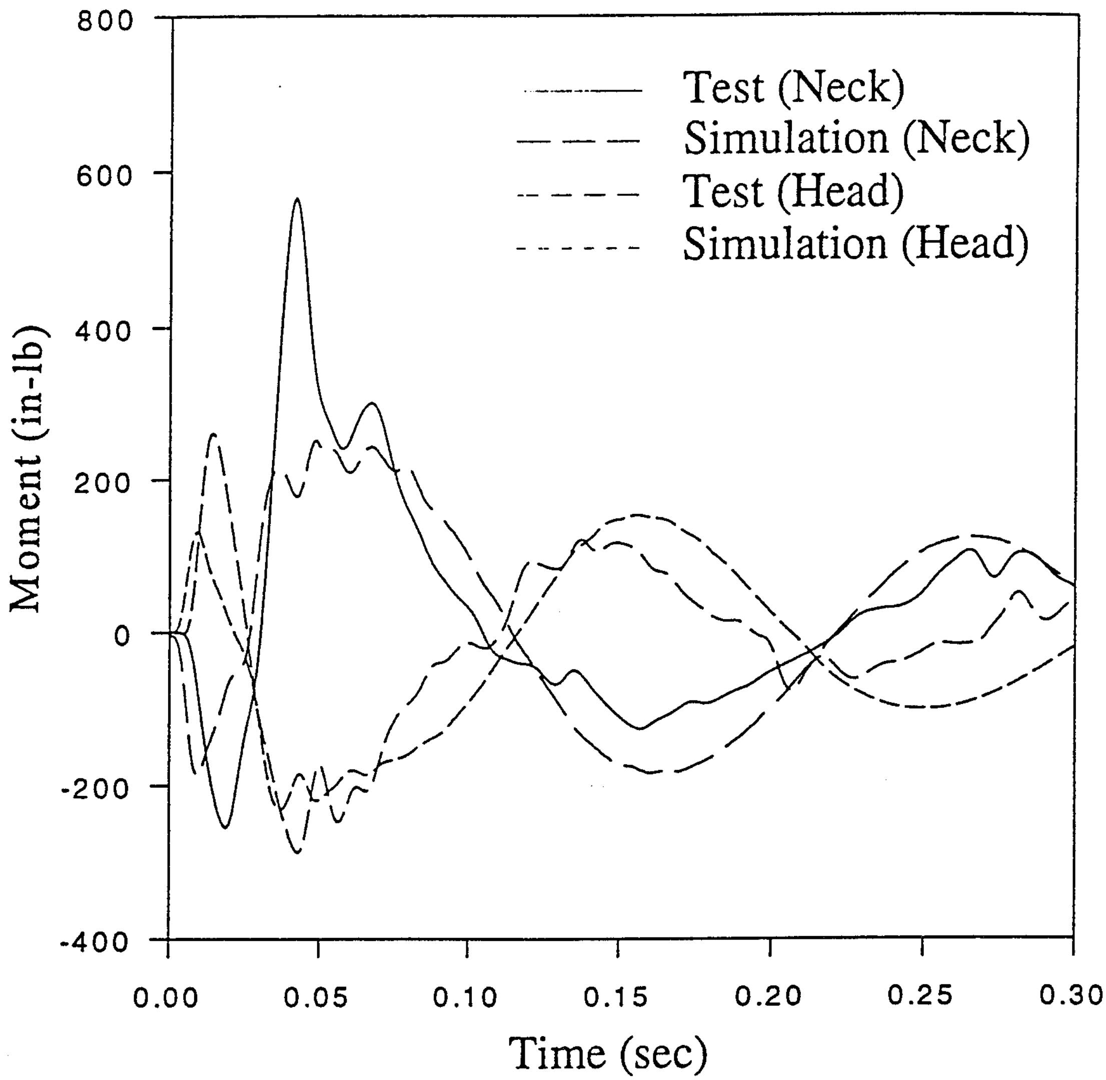


Figure 11. Head x Acceleration in HNP 20^0 Flexion Test

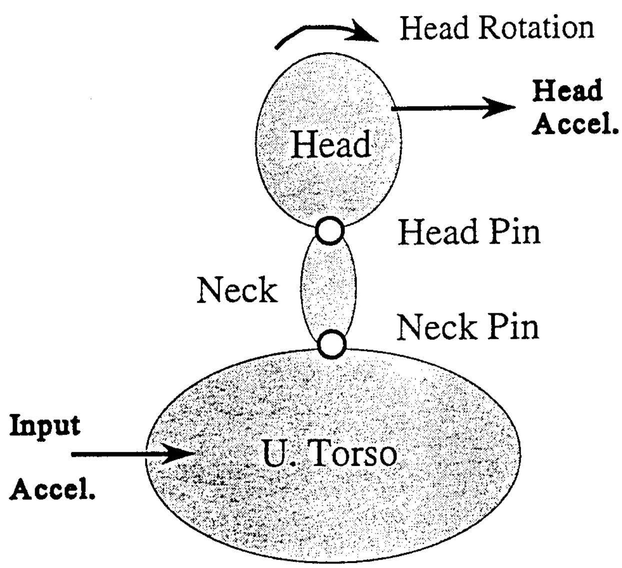


Head x acceleration in HNP 120^0 flexion test

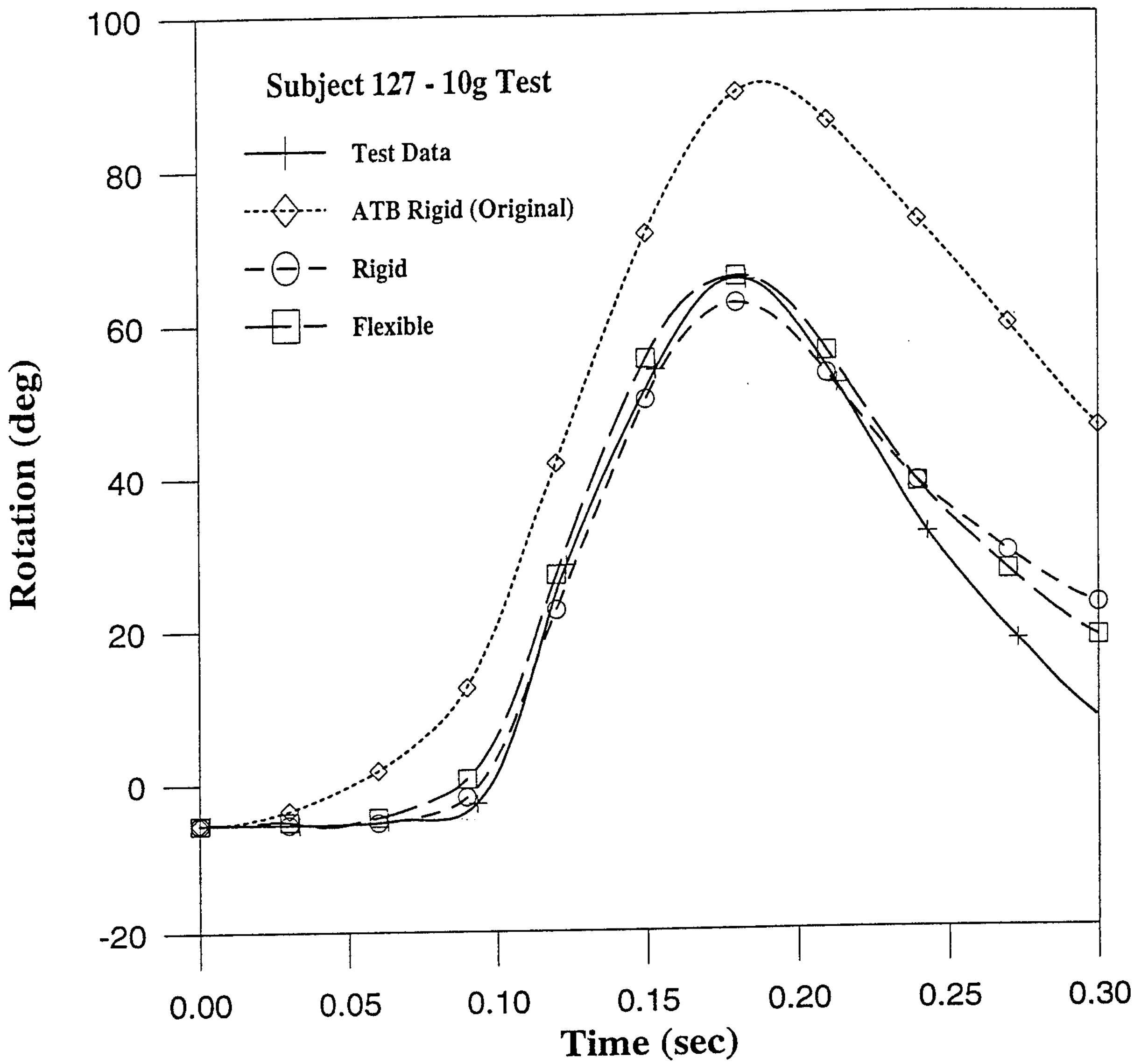


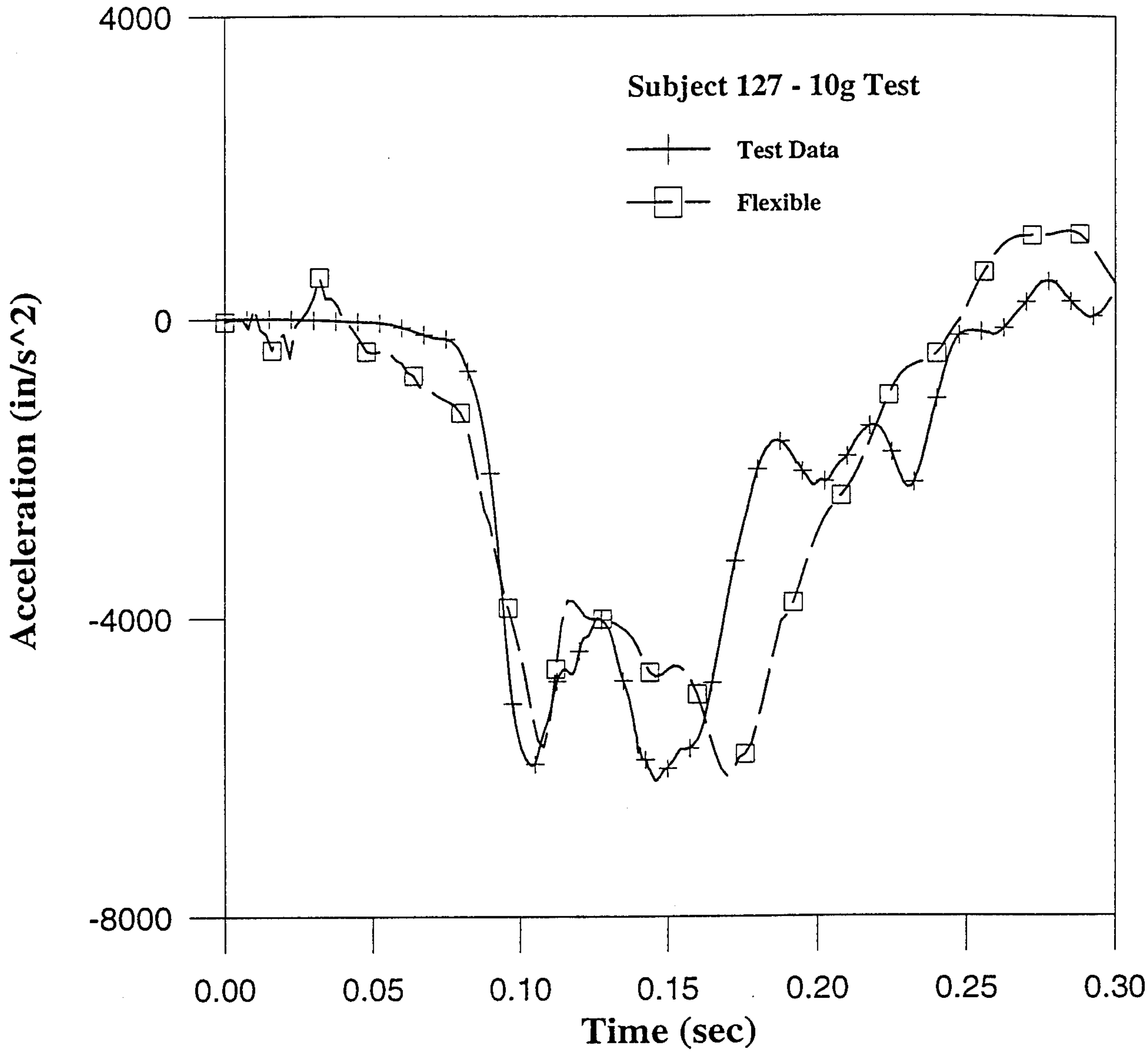
Moments for 60⁰ flexion and 65⁰ lateral tests

NBDL SLED TEST (4 - 12 g's)

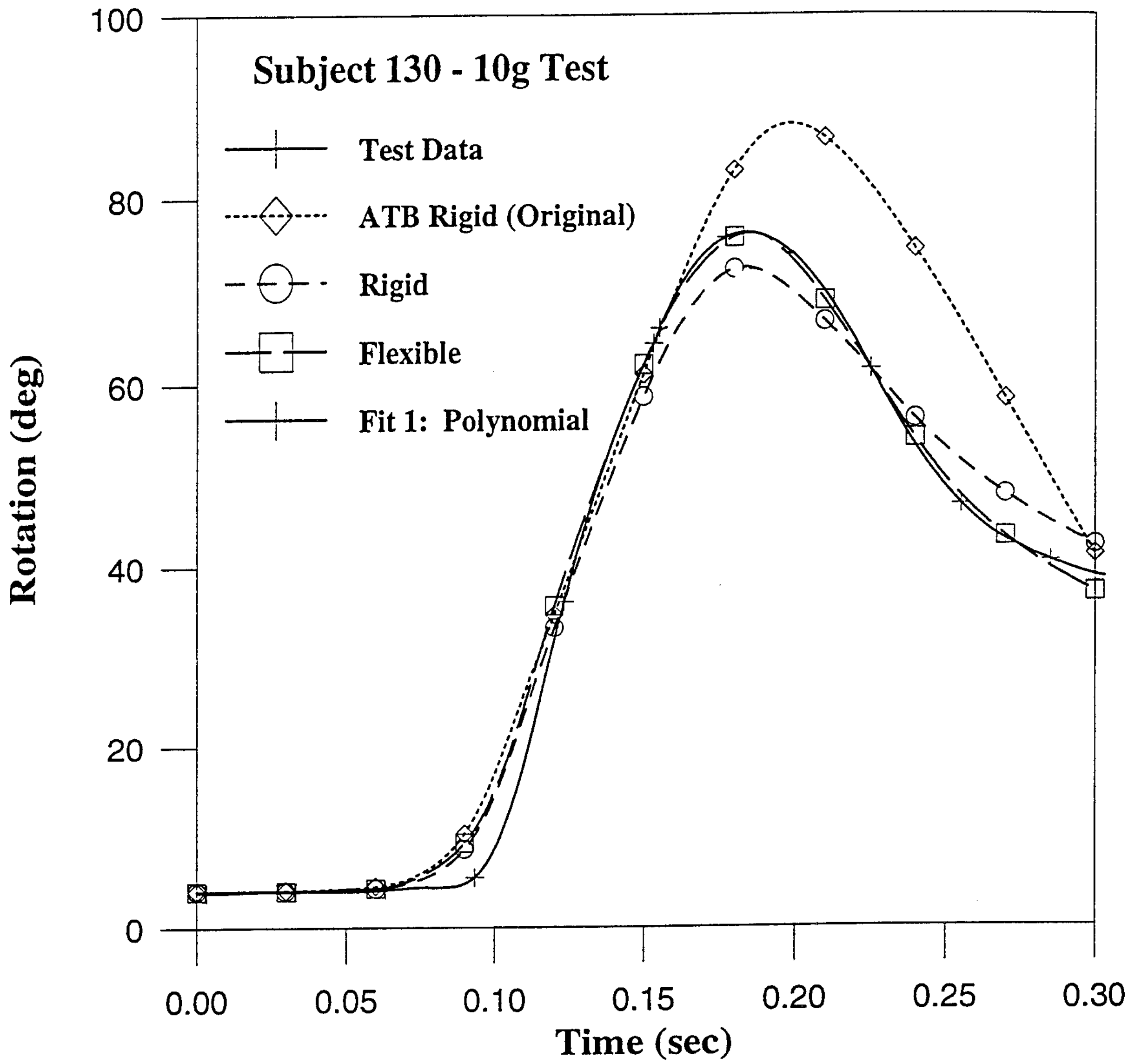


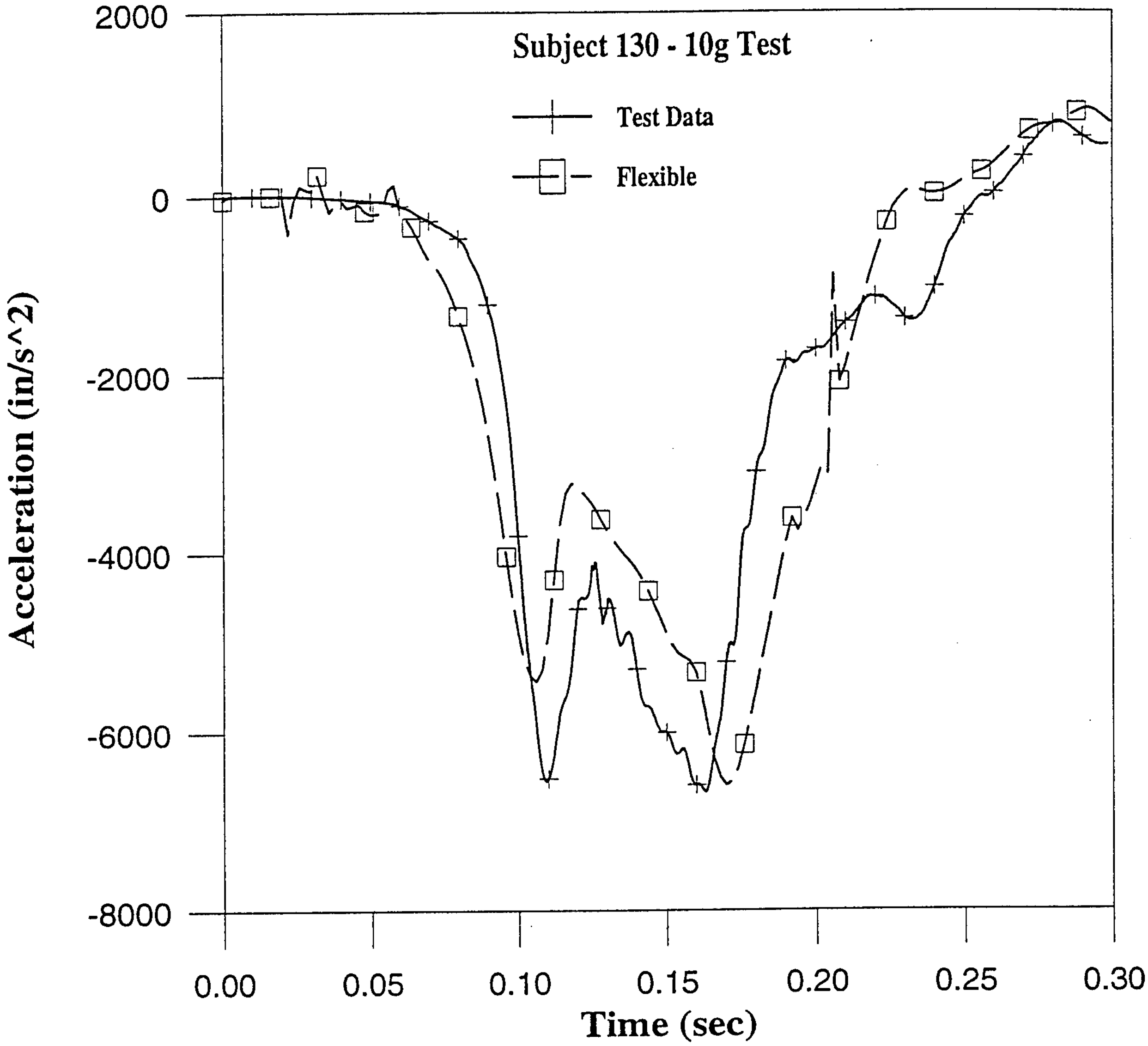
Torso-Head-Neck Model for Sled Test


Subject 127 - 10g Test
Test Data
ATB Rigid (Original)
Rigid
Flexible
Rotation (deg)
Time (sec)
100
80
60
40
20
0
-20
0.00
0.05
0.10
0.15
0.20
0.25
0.30

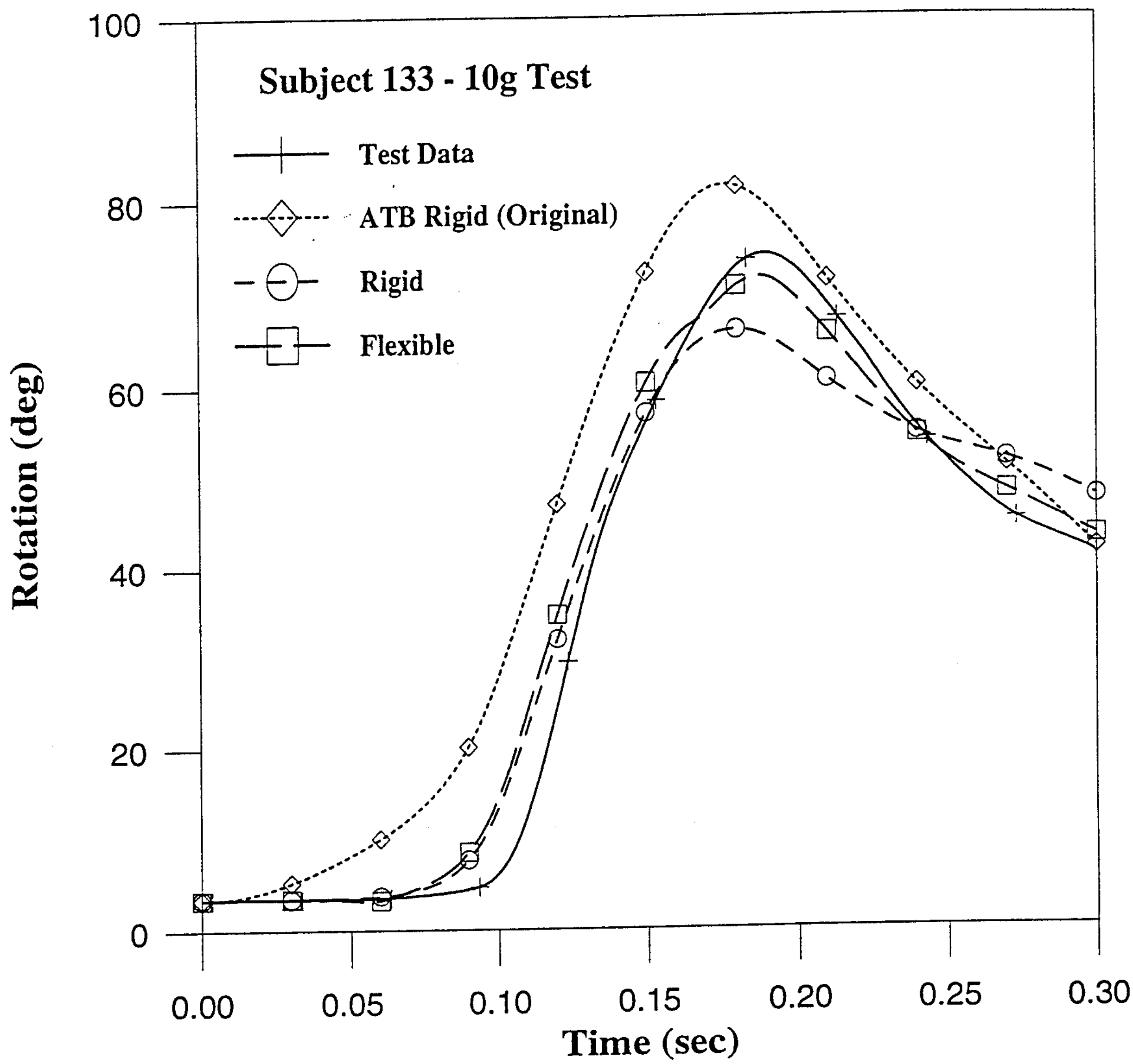


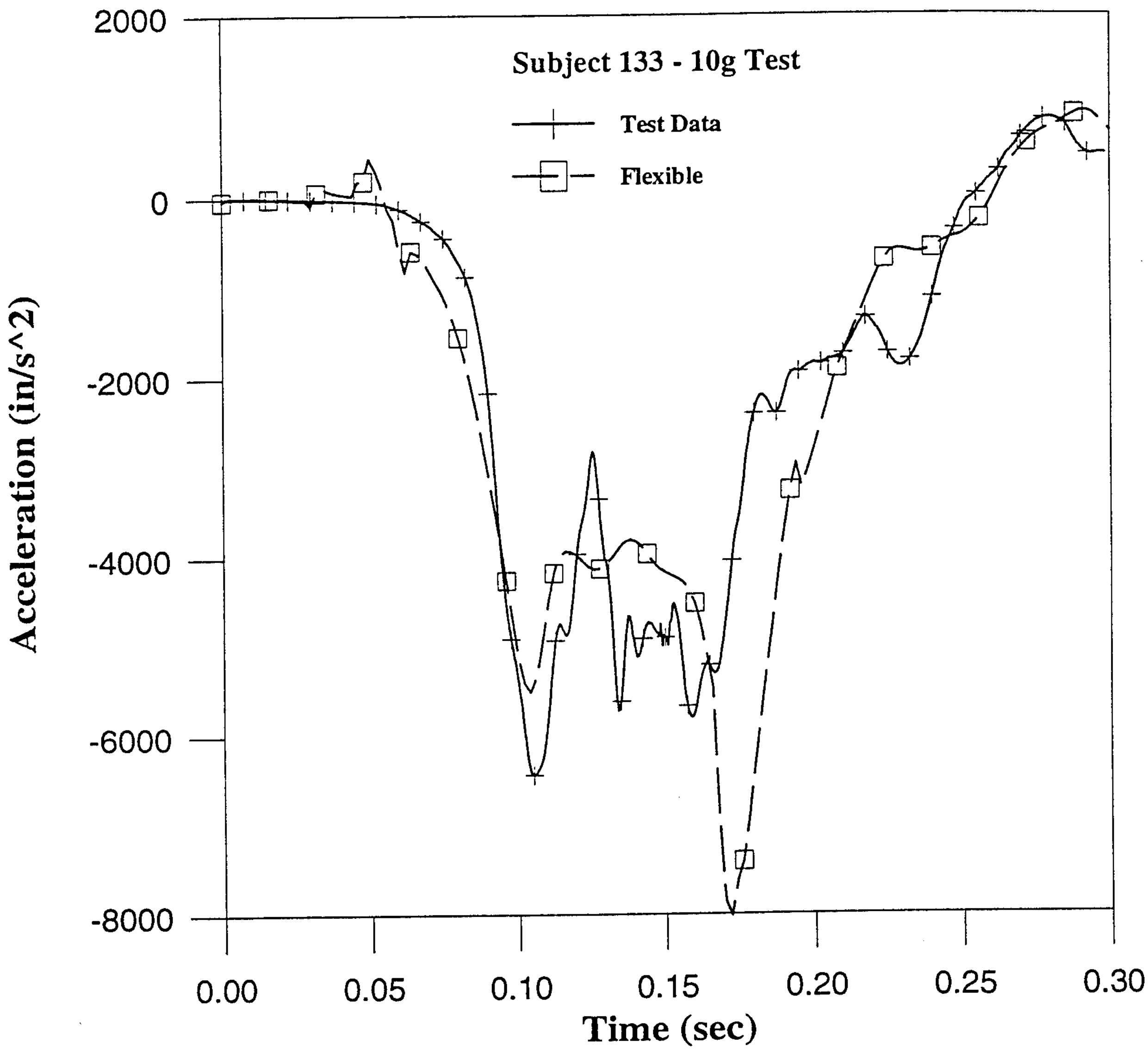
Subject 127 - 10g Test
Test Data
Flexible
4000
0
-4000
-8000
Acceleration (in/s^2)
0.00
0.05
0.10
0.15
0.20
0.25
0.30
Time (sec)


Subject 130 - 10g Test
Test Data
ATB Rigid (Original)
Rigid
Flexible
Fit 1: Polynomial
Rotation (deg)
Time (sec)
100
80
60
40
20
0
0.00
0.05
0.10
0.15
0.20
0.25
0.30

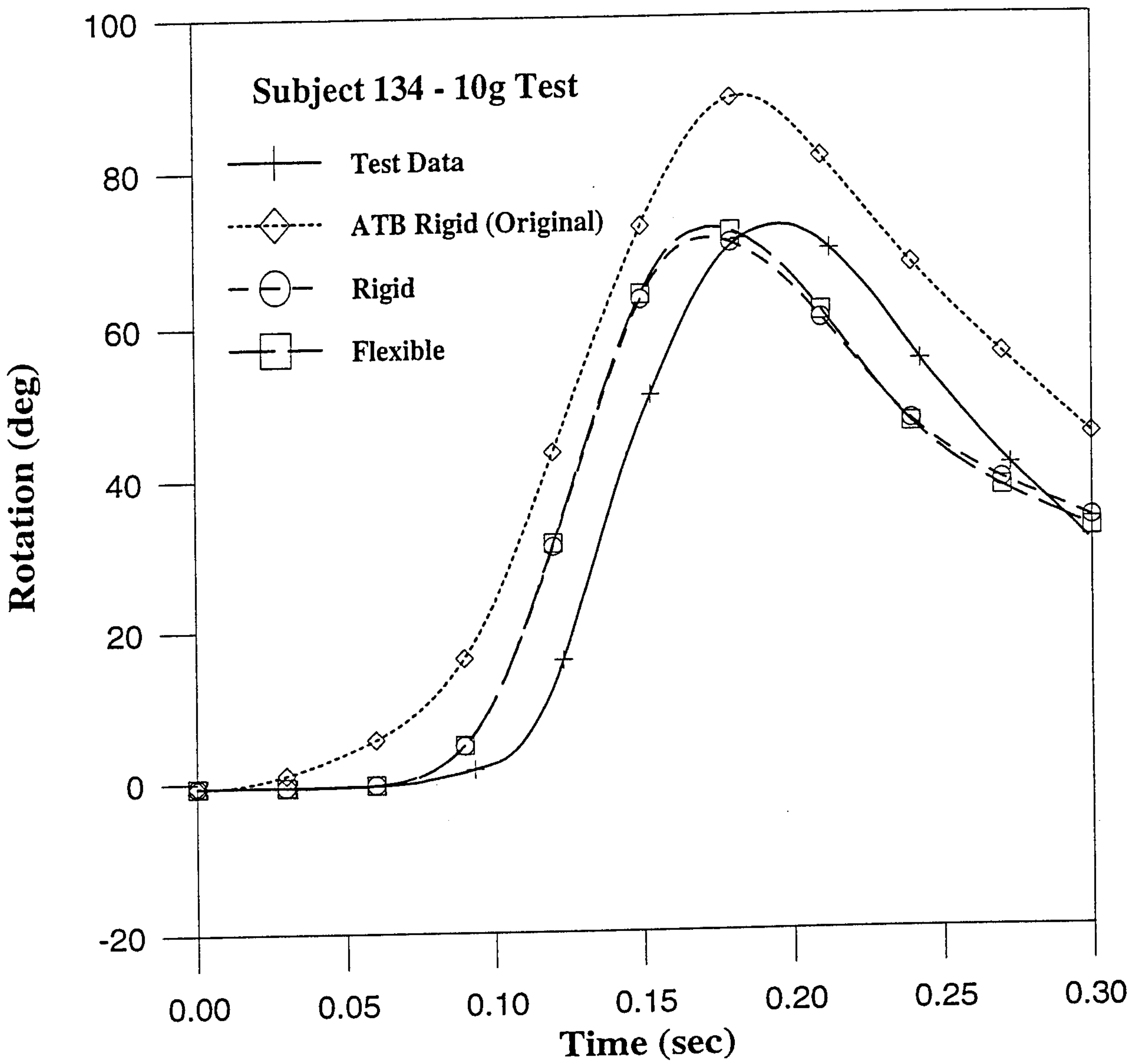


Subject 130 - 10g Test
Test Data
Flexible
2000
0
-2000
-4000
-6000
-8000
Acceleration (in/s^2)
0.00
0.05
0.10
0.15
0.20
0.25
0.30
Time (sec)

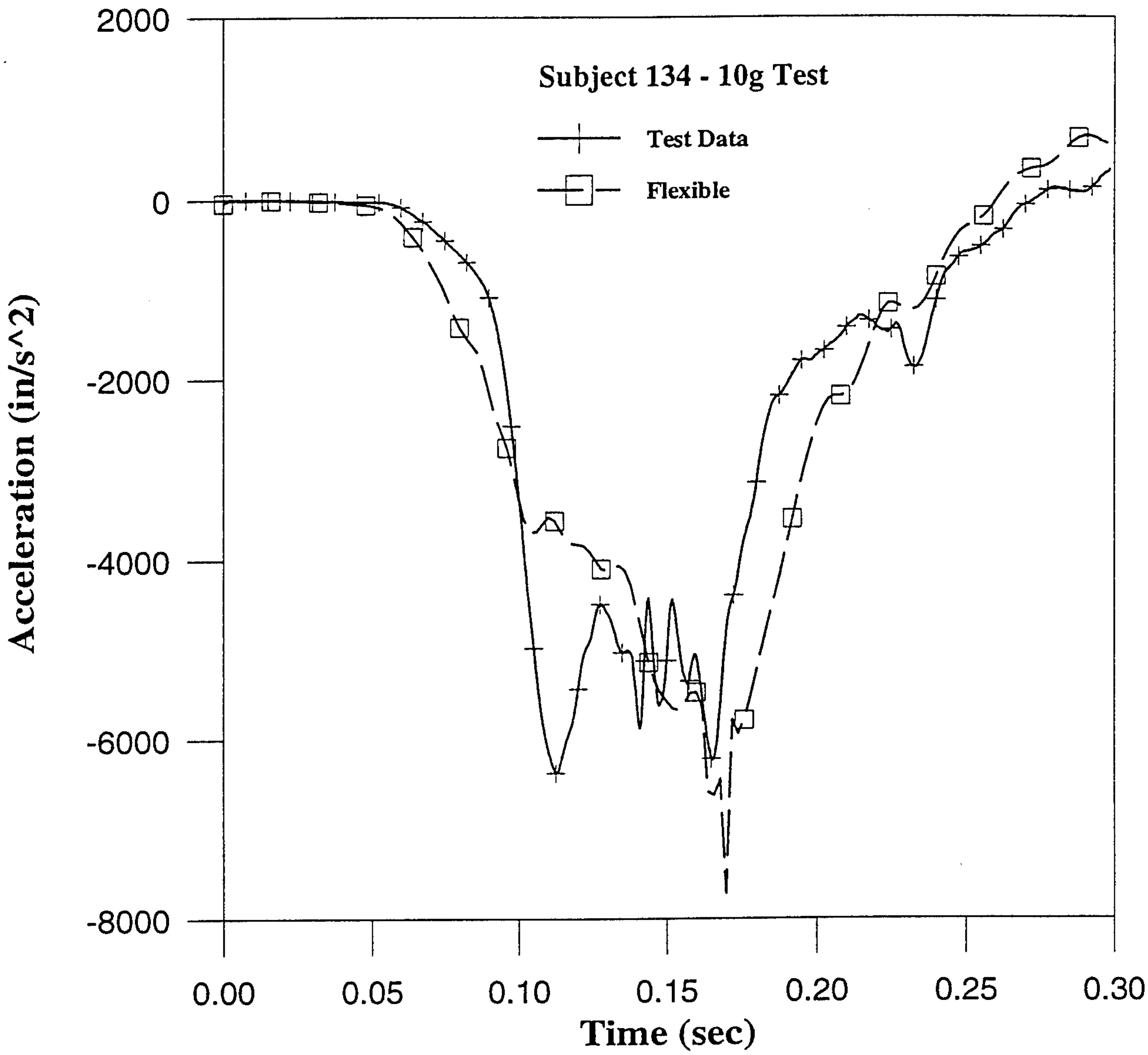

Subject 133 - 10g Test
Test Data
ATB Rigid (Original)
Rigid
Flexible
Rotation (deg)
100
80
60
40
20
0
0.00
0.05
0.10
0.15
0.20
0.25
0.30
Time (sec)



Subject 133 - 10g Test
Test Data
Flexible
2000
0
-2000
-4000
-6000
-8000
Acceleration (in/s^2)
0.00
0.05
0.10
0.15
0.20
0.25
0.30
Time (sec)



Subject 134 - 10g Test
Test Data
ATB Rigid (Original)
Rigid
Flexible
100
80
60
40
20
0
-20
Rotation (deg)
0.00
0.05
0.10
0.15
0.20
0.25
0.30
Time (sec)



Subject 134 - 10g Test
Test Data
Flexible
2000
0
-2000
-4000
-6000
-8000
Acceleration (in/s^2)
0.00
0.05
0.10
0.15
0.20
0.25
0.30
Time (sec)

The Incorporation of Anatomically Correct Geometric Joint Surfaces into the ATB Model

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IL

Clinical Motivation for Knee Testing

Effect of:

- surgical repair/reconstruction
- injury/disease
- dyplastic muscle forces

on kinematics and related contact stresses within the knee joint

ORL Diarthrodial Joint Research Program

- Experimental studies on fresh frozen human cadavers
  - joint geometry via stereophotogrammetry
  - kinematics via coordinate measuring machine
- Computational modeling
  - constitutive models
  - rigid body joint models [static and ATB]
  - FEM models in conjunction with RPI
- Replace SPG data used in models with MRI and CAT scan data from clinical studies

Purpose/Applications

- Provide a more physiologically realistic joint model within the ATB Model
- Study the effects of varying muscle forces on the resultant contact patterns within the joint
- Study the effects of various surigcal procedures on the resultant contact patterns within the joint
- Use the time histories of position and orientation of the SPG surfaces as input for the detailed FEM models to compute the resultant stress and strain within the cartilage of the joint

ORL Approach to Joint Modeling
Experimental

- Obtain material parameters for articular cartilage by indentation

- Use SPG to obtain precise geometry of:
  - articular cartilage surface
  - underlying bone surface
  - cartilage thickness map

- Determine joint kinematics for different experimental conditions using ORL joint testing rig

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Material Properties of Articular Cartilage

Site-Specific Material Properties

- Compressive properties from biphasic indentation studies (Mow et al., 1980, 1989; H_A, ν_s, k)
- Properties determined as a function of location
- Intrinsic viscoelastic properties of solid matrix

Site-Specific Correlations with Biochemistry

- Biochemical properties; water content, collagen and proteoglycans
- Determined at same site as biomechanical properties

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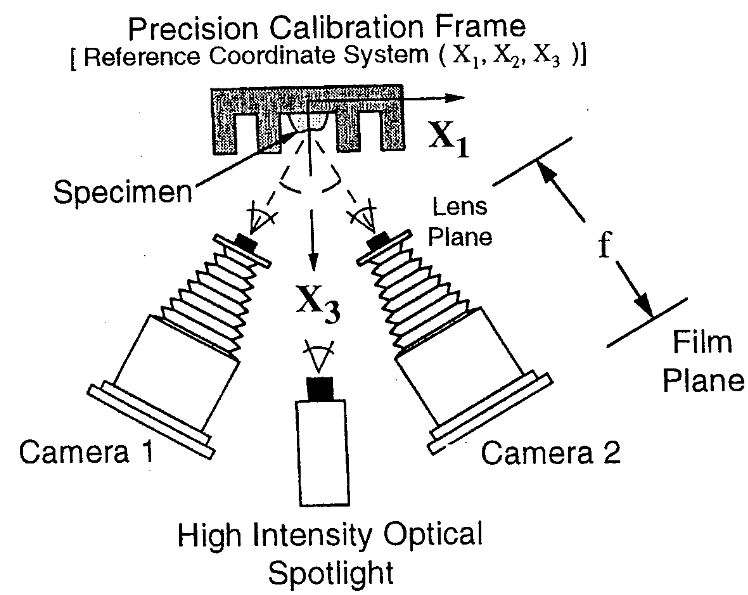
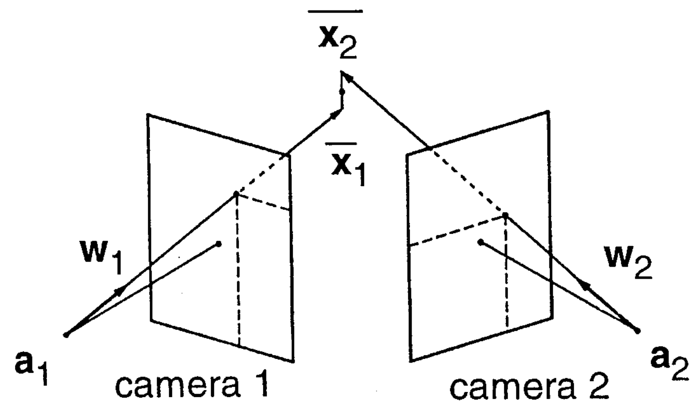
Reconstruction of a 3-D Surface via SPG



3-D SPG Spatial Point Reconstruction From 2 Photographs



Stereophotometrically Determined Articular Surface and Bone Geometries

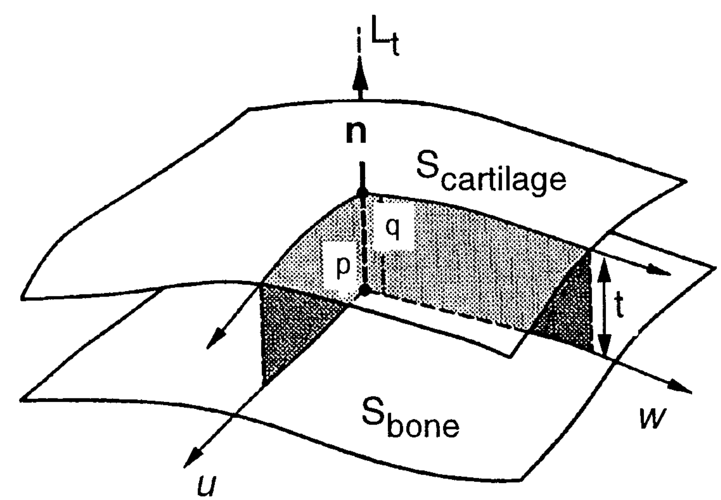
Attributes

- High accuracy (±90 μm) and precision
- Noninvasive during experimentation
- Compares well with other methods, .eg. Fuji film

Knowledge Base

- 3D B-spline representation of articular and bony surfaces
- Cartilage thickness maps
- Surface curvatures for stress analysis
- Contact areas in conjunction with kinematics

SPG Thickness Calculation



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Kinematic Studies

- Joint testing rig rigidly maintains joint configuration
  - applies physiologic muscle loads at prescribed lines of action
  - applies axial load simulating joint reaction force
- Coordinate measuring machine rigidly attached to joint testing rig
  - obtains joint kinematics
  - obtains related joint kinematics

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  - obtain related joint kinematics

Data Obtained With Coordinate Measuring Machine

- X,Y,Z coordinates for two sets of triads per bone yields position ($\pm$ 20 μm) and orientation (0.05°) of each bone in fixed reference frame
- Muscle lines of action, origin and insertion points in local coordinates
- Ligament attachment points on proximal and distal bones in local coordinates
- Bone contours in local coordinates
- Relationship of precise SPG cartilage and bone surfaces to local coordinates

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Data Obtained With Coordinate Measuring Machine

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- Ligament attachment points on proximal and distal bones in local coordinates
- Bone contours in local coordinates
- Relationship of precise SPG cartilage and bone surfaces to local coordinates

CONTACT AREA DETERMINATION

- Articular surface and bone surface geometry obtained by SPG
- Surface geometry related to kinematics by 3D CMM
- Kinematics of bones in ref. coord. obtained by 3D CMM
- Rigid body assumption permits determination of contact area by use of proximity criterion

Joint Coordinate Systems

- Obtain bone contours from CMM at 10 mm intervals on shaft and 5 mm intervals at bone end
- Obtain cartilage surface(s) from SPG
- Transform both sets of data to local coordinates of bone

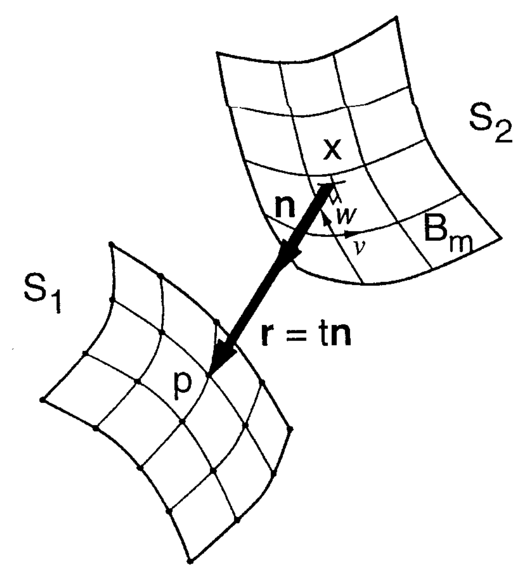
Joint Coordinate Systems

- Use either centroids or landmarks from bone contours
- Use either centroids or spherical surface fits from SPG 3-D surface fits
- Create right-handed, orthogonal coordinate systems in local coordinates of the bone
- Produces more consistent kinematic results

ATB Modeling Approach

- Muscles modeled as a constant force applied at the insertion point, in the direction of the origin
- Ligaments modeled as spring dampers between insertion and origin points
- SPG surfaces act as nondeformable surfaces that penetrate each other

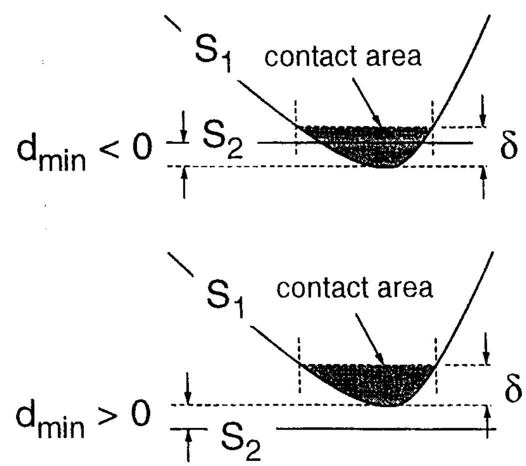
SPG Proximity Calculations



ATB Model Modifications

- Muscle force modifications in subroutine SPDAMP
- SPG surface hooks in subroutines:
  - SINPUT
  - CONTCT
- In-house solid model of VIEW for SGI to display:
  - ellipsoids
  - hyperellipsoids
  - SPG surfaces

SPG Contact Area Between Two Undeformable Surfaces



ATB-SPG Prescribed Motion Contact Area Test

- Opposing SPG surfaces attached to different segments, no contact force computed
- Motion of 1 segment prescribed relative to another segment based on known kinematic data
- 6 DOF spline-fit C cards (option 4) used for displacement and orientation to interpolate between known points for a continuous motion with constant velocity

ATB-SPG Prescribed Motion Contact Area Test

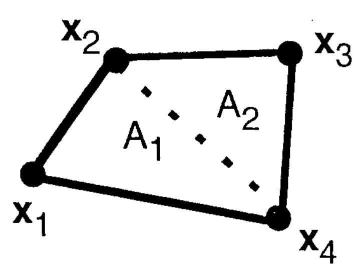
- Study done for greyhound (patella moving in groove of femur) and human (humerus moving on the glenoid)
- Computed contact area as a function of flexion angle (knee) and elevation (shoulder)
- Map of contact area as a function of time depicted in movie format using in-house View_SGI

ATB - SPG Surface Stability Test

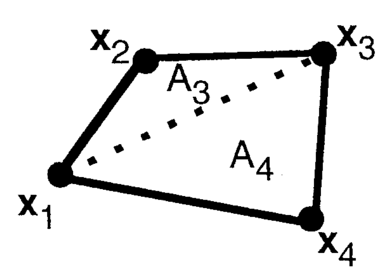
- Rectangular plane dropped on right half cylinder (unstable configuration)
- Undamped, frictionless elastic contact to check numerical stability of ATB-SPG contact calculations
- Applied symmetric spring dampers with various damping coefficents to observe equilibrium results

ATB-SPG Contact Force

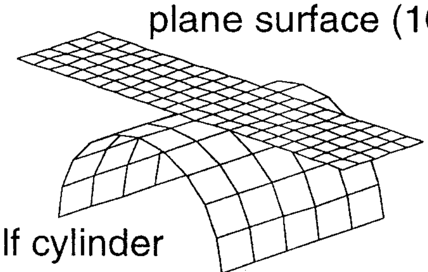
- Elastic or biphasic constitutive model
- Overlap between bicubic spline patches
- Contact area average of 4 triangles created from 4 nodes in real (nonparametric space)



$$A_a = \frac{\sum_{i=1}^{4} A_i}{2}$$

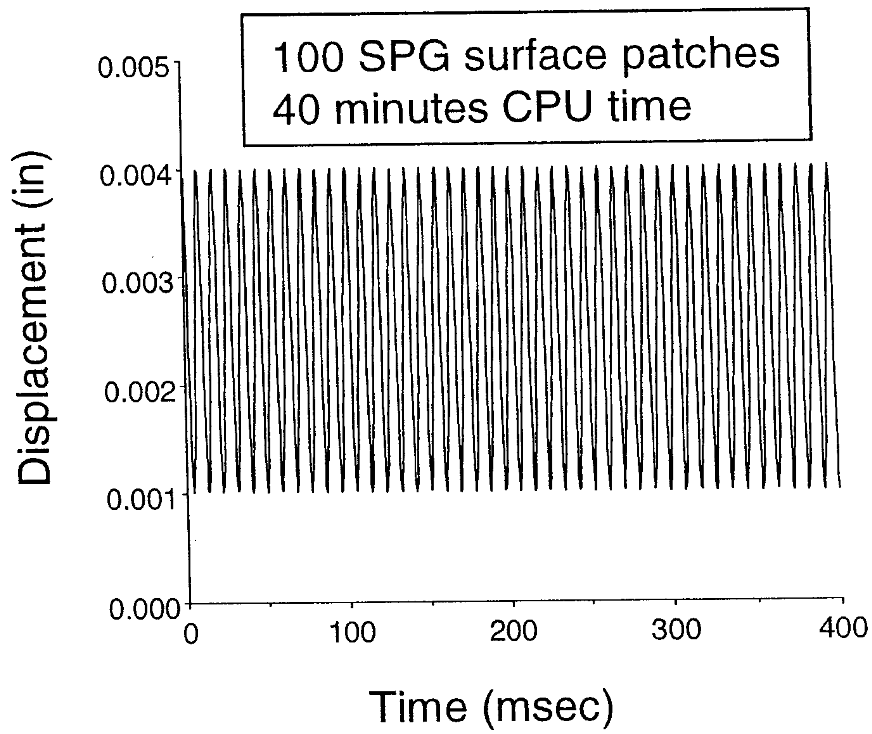


SPG Plane Surface Bouncing on SPG Cylindrical Surface

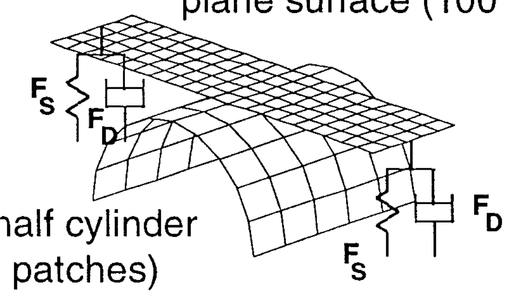


unconstrained

SPG Plane Displacement Completely Unconstrained

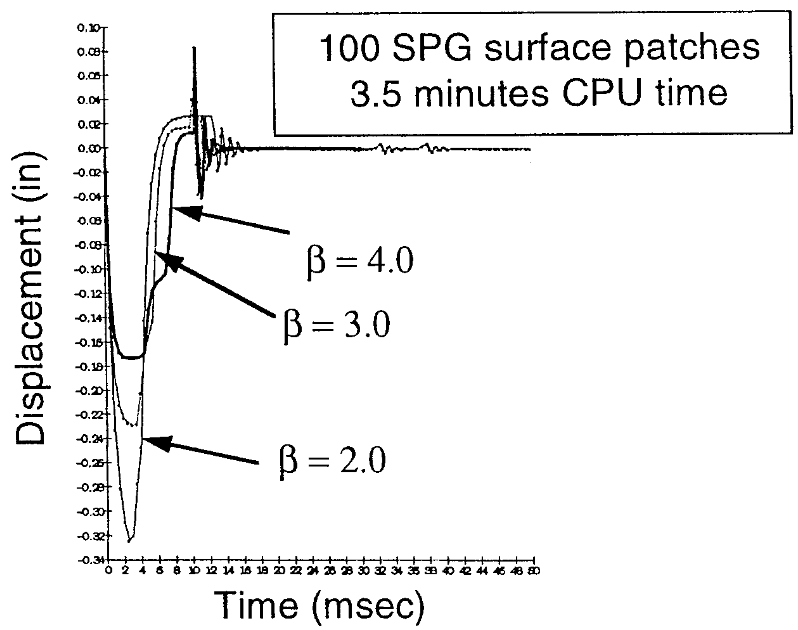


SPG Plane Surface Bouncing on SPG Cylindrical Surface



with constraints

SPG Plane Displacement
Spring-Damper Constraint



Future Directions

- Modify contact algorithm to use coarse SPG grid first, then full grid as convergence is approached
- Incorporate more realistic, nonlinear model for the ligaments with experimentally determined properties
- Provide for finite-width muscle attachements with sliding contacts
- Perform validation study using just completed knee study (n=6) with known loads and kinematics for 0° through 120° of flexion

Future Directions

- Develop a similar orthogonal coordinate system for the shoulder based on mathematical fits to the anatomical data

- Perform similar validation study using recent shoulder study (n=10) with known loads and kinematics for 0° through 110° of elevation in the scapular plane

- Relate the joint coordinate systems to the principal axes coordinate system of the segment

Columbia University ORL Knee Group

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R.P. Grelsamer, M.D.

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ACKNOWLEDGEMENTS

- Bristol-Myers Squibbs/Zimmer Center of Excellence in Orthopaedic Research Award
- Depuy Career Development Award from the Orthopedic Research and Education Foundation
- National Science Foundation High Performance Computing and Communication Grand Challenge Grant

RELATED COLUMBIA ORL PUBLICATIONS

Material Properties / Constitutive Models

"Biphasic indentation of articular cartilage: I. theoretical analysis," Mak A.F., Lai W.M., Mow V.C., *J. Biomechanics,* 20:703-714, 1987.

"A finite element formulation of the nonlinear biphasic model for articular cartilage and hydrated soft tissue including strain-dependent permeability," Spilker R.L., Suh J.-K., Mow V.C., in *Computational Methods in Bioengineering,* ASME, ed. R.L. Spilker and B.R. Simon, New York, New York, pp. 81-92, 1988.

"Biphasic indentation of articular cartilage: II. a numerical algorithm and an experimental study," Mow V.C., Gibbs M.C., Lai W.M., Zhu W.B., Athanasiou K.A., *J. Biomechanics,* 22:853-861, 1989.

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"Stereophotogrammetric determination of joint anatomy and contact areas," Soslowsky L.J., Ateshian G.A., Mow V.C., in *Biomechanics of Diarthrodial Joints, II,* ed. by V.C. Mow, A. Ratcliffe, S.L.-Y. Woo, New York, New York, Springer-Verlag, pp. 243-268, 1990.

"Quantitation of articular surface topography and cartilage thickness in knee joints using stereophotogrammetry," Ateshian G.A., Soslowsky L.J., Mow V.C., *J. Biomechanics,* 24:761-776, 1991.

"Articular geometry of the glenohumeral joint," Soslowsky L.J., Flatow E.L., Bigliani L.U., Mow V.C., *Clin. Orthop. Rel. Res.,* 285:181-190, 1992.

"Quantification of *in situ* contact areas at the glenohumeral joint: A biomechanical study," Soslowsky L.J., Flatow E.L., Bigliani L.U., Pawluk R.J., Ateshian G.A., Mow V.C., *J. Orthop. Res.,* 10:524-534, 1992.

"A new stereophotogrammetry method for determining *in situ* contact areas in diarthrodial joints: A comparison study," Ateshian G.A., Kwak S.D., Soslowsky L.J., Mow V.C., *J. Biomechanics,* 27:111-124, 1994.

"Quantitative anatomy of the knee," in *Knee Surgery,* Ateshian G.A., Colman W.W., Mow V.C., ed. by F.H. Fu, C.D. Harner, K.G., Vince, M.D. Miller, Williams and Wilkens, Baltimore, MD, pp. 101-130, 1994.

"Anatomy and mechanics of the patellofemoral joint," Grelsamer R.P., Colman W.W., Mow V.C., *Arthroscopy Review,* 2:178-188, 1994.

Experimental Studies

"A 6 DOF knee testing device to determine patellar tracking and patellofemoral joint contact area via stereophotogrammetry," Gardner T.R., Ateshian G.A., Grelsamer R.P., Mow V.C., *ASME Advances in Bioengineering* BED, 28:279-280, 1994.

"A new 6 degrees of freedom knee testing apparatus for studies on experimental surgical techniques," Mow V.C., Henry J.H., Grelsamer R.P., Ahmad C.S., Kwak S.D., Ateshian G.A., Gardner T.R., presented at Sports Medicine 2000, Stockholm, Sweden, June 6-8, 1995.

"The influence of iliotibial band tension on patellar tracking and patellofemoral contact," Ahmad C.S., Kwak S.D., Grelsamer R.P., Henry J.H., Gardner T.R., Ateshian G.A., Mow V.C., Amer. Acad. of Orthop. Surgeons 1996 Annual Meeting, submitted.

Joint Modeling

"An asymptotic solution for two contacting biphasic cartilage layers," Ateshian G.A., Lai W.M., Zhu W.B., Mow V.C., *J. Biomechanics,* 27:1347-1360, 1994.

"Computer simulation of glenohumeral and patellofemoral subluxation: Estimating pathological articular contact," Flatow E.L., Ateshian G.A., Soslowsky L.J., Pawluk R.J., Grelsamer R.P., Mow V.C., Bigliani L.U., *Clin. Orthop. Rel. Res.,* 306:28-33, 1994.

"An anatomically based 3-D coordinate system for the knee joint," Kwak S.D., Blankevoort L., Ahmad C.S., Gardner T.R., Grelsamer R.P., Henry J.H., Ateshian G.A., Mow V.C., ASME 1995 Winter Annual Meeting, accepted.

"Development of multibody model for diarthrodial joints using accurate 3-D cartilage and bone surfaces," Kwak S.D., Ateshian G.A., Blankevoort L., Ahmad C.S., Gardner T.R., Grelsamer R.P., Mow V.C., 1995 Annual Fall Meeting of the Biomed. Eng. Society, submitted.

Generator of Body Data (GEBOD) Program

Huaining Cheng
Systems Research Laboratories, Inc.

Louise A. Obergefell, Ph.D.
Armstrong Laboratory

Annette L. Rizer
Systems Research Laboratories, Inc.

OBJECTIVE

- **Automated generation of data sets for human and dummy rigid body dynamics modeling**

HISTORY

- 1973 Generator of Occupant Data (GOOD)
- 1983 Generator of Body Data (GEBOD)
  - » Use of anthropometric survey data
  - » 15 segments and 14 joints for male, female, and child subjects
- 1989 conversion program for use with MADYMO

HISTORY

- 1991 GEBODIII
  - » Use of stereophotometric data for inertial property and joint location calculations
  - » Separate forearm and hand segments
  - » Principal moment of inertia axes rotated from local axes
  - » Manikin data sets
  - » Joint resistive torque properties

HISTORY

- 1994 GEBODIV
  - » Correction to joint center locations
  - » New documentation
- Current version GEBODIV.1
  - » Minor improvements

GEBOD PROGRAM

- Interactive program
- Two methods for selection subject
  - » Specify weight and/or standing height
  - » User-supplied dimensions
- English or metric units for input and output
- Separated or combined hand and forearm segments

DATA SETS PROVIDED

- Child (2-19 years)
- Adult human male (unit or percentile)
  - » Weight range: 118 - 264 lbs
  - » Height range: 62.17 - 77.64 in
- Adult human female (unit or percentile)
  - » Weight range: 85 - 200 lbs
  - » Height range: 56.93 -72.05 in
- Hybrid II and Hybrid III manikins (50th %tile)

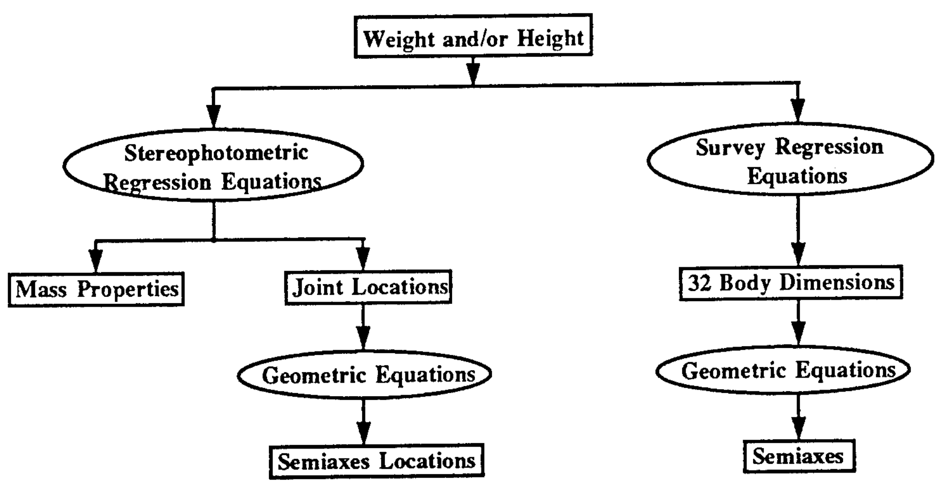
DATA IN DATA SETS

- Segment mass
- Segment center of mass
- Segment principal moments of inertia
- Orientation of principal axes
- Contact ellipsoid dimensions & location
- Joint locations
- Joint ranges of motion & resistive torque properties

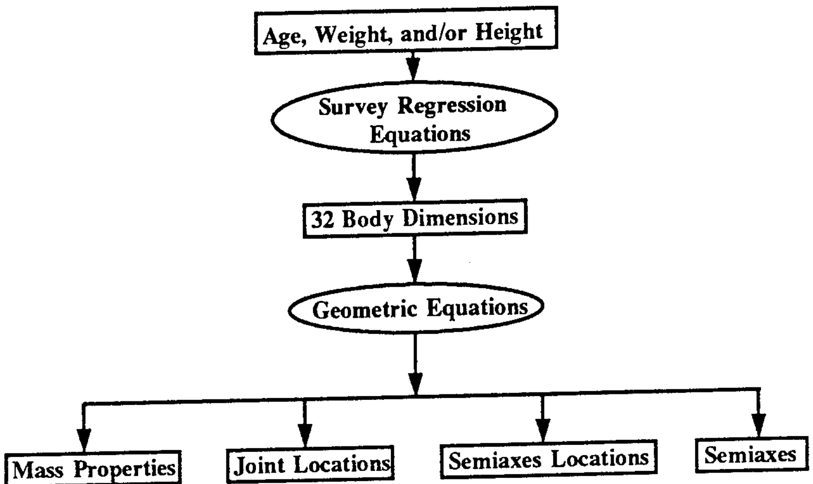
USER-SUPPLIED DIMENSIONS

No	Dimension	No	Dimension
0	Weight	16	Hip Breadth, Standing
1	Standing Height	17	Shoulder to Elbow Length
2	Shoulder Height	18	Forearm-Hand Length
3	Armpit Height	19	Biceps Circumference
4	Waist Height	20	Elbow Circumference
5	Seated Height	21	Forearm Circumference
6	Head Length	22	Waist Circumference
7	Head Breadth	23	Knee Height, Seated
8	Head to Chin Height	24	Thigh Circumference
9	Neck Circumference	25	Upper Leg Circumference
10	Shoulder Breadth	26	Knee Circumference
11	Chest Depth	27	Calf Circumference
12	Chest Breadth	28	Ankle Circumference
13	Waist Depth	29	Ankle Height, Outside
14	Waist Breadth	30	Foot Breadth
15	Buttock Depth	31	Foot Length

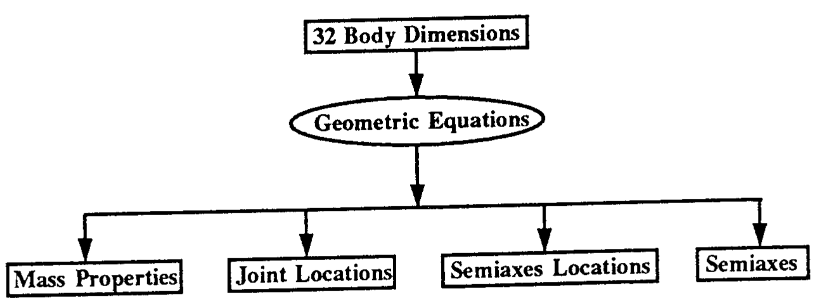
ADULT OPTIONS



CHILD OPTION



USER-SUPPLIED OPTION



STEREOPHOTOMETRIC DATA

- 31 male and 46 female subjects
  - » McConville, et al., 1980; Young, et al., 1983
- Thousands of data points
- Over 70 anthropometric landmarks
- Segmented by cut planes defined by landmarks
- Segment volumes determined
- GEBOD version of first use: GEBOD III

ANTHROPOMETRIC SURVEY DATA

- 2,420 male and 1,905 female subjects
  - » Grunhofer and Kroh, 1975; Clauser, et al., 1972
- 3,782 children aged 2 to 20 years
  - » Synder, et al., 1977
- Over 150 body dimensions measured
- GEBOD version of first use: GEBOD

JOINT CENTER LOCATION REGRESSION EQUATIONS

- Expressions for joint centers based on anthropometric landmarks
- Two separate groups for male and female subjects
- Regression equations are functions of weight and/or standing height
- Used in GEBOD III to determine specific joint center locations in the local reference system

MASS PROPERTY REGRESSION EQUATIONS

- Based on stereophotometric segment volumes
- Two separate groups for male and female subjects
- Functions of weight and/or standing height
- Used in GEBOD III to predict each segment's mass and principal moments of inertia

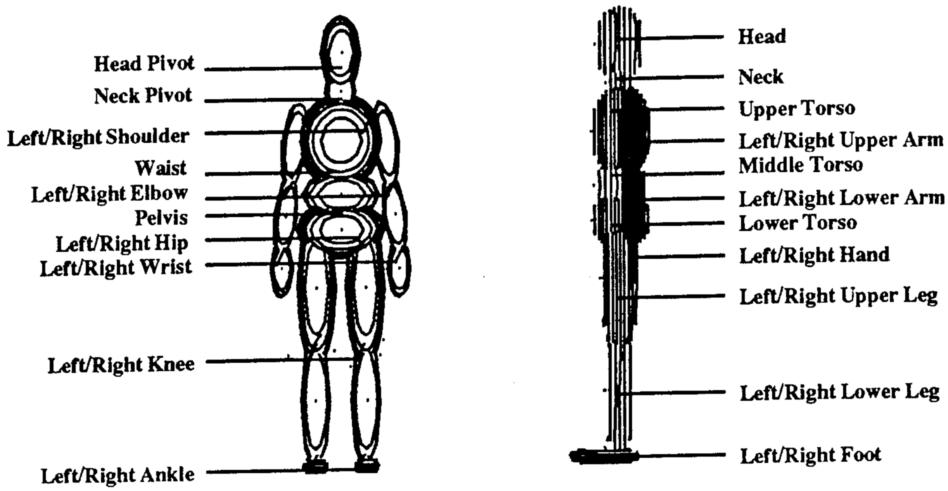
BODY DIMENSION SET REGRESSION EQUATIONS

- **Based on anthropometric survey**
- **Two separate groups for male and female**
- **Functions of weight and/or standing height**
  - » **Extra independent variable of age for child regression equations**

BODY DIMENSION SET REGRESSION EQUATIONS

- **32 body dimensions used**
  - » **Three additional dimensions used when separate hands modeled**
    #32: Hand breadth; #33: Hand length; #34 Hand depth
- **Used in GEBODIII to determine contact ellipsoid dimensions and locations**

EXAMPLE BODY CONFIGURATION



JOINT RESISTIVE CHARACTERISTICS

- **Resistive torque properties for spring torque, viscous torque, and coulomb friction**
- **Joint lock/unlock conditions**
- **Joint stop angles**
- **Obtained from a number of sources**

OUTPUT FILES

- Extension .TAB file
  - » A list of 35 body dimensions for the human data sets
  - » Labeled tables of the calculated data set

- Extension .AIN file
  - » ATB model input cards B.1 to B.6 in input ready format

SUMMARY

- Child, adult male and female, and Hybrid dummy data sets

- Interactive and flexible in amount of user input

- Provides the body data necessary for human body dynamic simulations

```
C:\ATB>gebodiv1


PROGRAM GEBOD
GEBOD GENERATES BODY DESCRIPTION DATA
SUITABLE FOR INPUT TO THE ATB MODEL
PLEASE ENTER A DESCRIPTION OF THE SUBJECT (<60 CHARS.)
male 72 inches tall and 195 lbs


ENTER FILENAME FOR ALL OUTPUT FILES,
EXTENSIONS WILL BE ASSIGNED:
ucp\m72-195



          1)    CHILD (2 - 19 YEARS)

          2)    ADULT HUMAN FEMALE

          3)    ADULT HUMAN MALE

          4)    USER-SUPPLIED BODY DIMENSIONS

          5)    SITTING HYBRID III DUMMY (50%)

          6)    STANDING HYBRID III DUMMY (50%)

          7)    HYBRID II DUMMY (50%)

ENTER NUMBER CORRESPONDING TO DESIRED SUBJECT TYPE
3


          1)    WEIGHT

          2)    STANDING HEIGHT

          3)    ALL OF THE ABOVE

ENTER NUMBER CORRESPONDING TO
PREDICTING DIMENSION(S) TO BE SUPPLIED
3


SELECT UNITS FOR WEIGHT
        1)      LB.
        2)      N.
        3)      %-TILE
 1

ENTER VALUE FOR WEIGHT
IN THE RANGE  118.0    , 264.0
195
```

```
SELECT UNITS FOR STANDING HEIGHT
        1)      IN.
        2)      M.
        3)      %-TILE
 1

ENTER VALUE FOR STANDING HEIGHT
IN THE RANGE  62.17     , 77.64
72


          1)    FOREARM AND HAND COMBINED

          2)    FOREARM AND HAND SEPARATED

ENTER THE NUMBER CORRESPONDING TO THE DESIRED LOWER ARM SEGMENTATION
1


SELECT UNITS FOR OUTPUT
        1)      ENGLSH
        2)      METRIC
 1


IS ATB MODEL FORMATTED OUTPUT DESIRED (Y/N) ?
y


IS IT DESIRED TO PRODUCE ANOTHER BODY DESCRIPTION DATA SET (Y/N) ?
n

FROM ARESULTS

C:\ATB>
```

```
C:\ATB\UCP>ndeck1
THE DEFAULT RESPONSE TO QUESTIONS IN THIS PROGRAM IS
<YES>.  A CR (CARRIAGE RETURN), Y, OR YES RESPONSE
WILL BE INTERPRETED AS AN AFFIRMATIVE RESPONSE.
ANY OTHER RESPONSE WILL BE INTERPRETED AS A
NEGATIVE RESPONSE.
ENTER COMMENT 80 MAX. PER LINE 160 CHRS IN TWO LINES
Example setup file using a standard vehicle interior and static pulse
Occupant from GEBOD, male 72 inches and 195 lbs
ENTER TOTAL SIMULATION TIME (SEC)
.2
------------------------------------------------------------------------
    1. FIRST COMMENT -
Example setup file using a standard vehicle interior and static pulse
    2. SECOND COMMENT -
Occupant from GEBOD, male 72 inches and 195 lbs
    3. TOTAL SIMULATION TIME =    .200

    4. NPRT ARRAY -
 1 2 3 4 5 6 7 8 9101112131415161718192021222324252627282930313233343536
 1 010 2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1
THESE ARE DEFAULT NPRT VALUES

DO YOU WISH TO MAKE ANY CHANGES ? <YES>
n
------------------------------------------------------------------------
    DIRECTORY OF OCCUPANT DATA LIBRARY

FILE NO.     FILE NAME

  1           SIXYRCHD
  2           95THMALE
  3           PART572
  4           ESTP572
  5           TEST 50-50-M
  6           PED50TH
  7           75-75-M
  8           25-25-M
  9           5-5-F
 10           95THMLOCC
 11           50-50-M
 12           15-95-M
 13           37-37-F


ENTER THE DESIRED FILE NO. FOR INPUT DATA
ENTER 0 TO USE A GEBOD FILE
0
ENTER THE FILENAME OF THE GEBOD FILE TO USE
m72-195.ain
```

```
    DIRECTORY OF VEHICLE DECELERATION DATA LIBRARY

FILE NO.      FILE NAME

  1             0G STATIC
  2             RX-7 NCAP
  3             PULSE #1
  4             OMNI SLED
  5             VOLVO BARRIER
  6             SIDE IMP (DRIVER
  7             FIAT DATA
  8             SUBARU BRAT
  9             G30F

ENTER THE DESIRED FILE NO. FOR INPUT DATA
1
VEHICLE DECELERATION CHOSEN IS :
0G STATIC
IS THIS O.K. ? <YES>
y
------------------------------------------------------------------------------
    DIRECTORY OF VEHICLE INTERIOR DATA LIBRARY

FILE NO.      FILE NAME

  1             MAZDA RX-7
  2             '88 CHEV. BERETT
  3             STD VEH # 1
  4             VOLVO
  5             OMNI-MOD
  6             OMNI-STD
  7             OMNI-STD(UNR)
  8             SIDE IMPACT BASE
  9             PEDVEH1
 10             STD VEH # 2
 11             CONTACT CHK
 12             G24
 13             FORKLIFT

ENTER THE DESIRED FILE NO. FOR INPUT DATA
10
VEHICLE INTERIOR CHOSEN IS :
STD VEH # 2
IS THIS O.K. ? <YES>
y
------------------------------------------------------------------------------
------------------------------------------------------------------------------
------------------------------------------------------------------------------
Stop - Program terminated.


C:\ATB\UCP>
```

```
C:\ATB\UCP>ndeck2
DO YOU WANT ALL SEGMENTS TO BE RIGID (YES OR NO) ? :
n
WILL ALL SEGMENTS HAVE THE SAME PROPERTIES ?:
y
------------------------------------------------------------------------
***** ALL SEGMENTS WILL HAVE THIS VALUE *****
FUNCTION SELECTION - SEGMENT NO.   1 ,  LT
FORCE - DEFLECTION FUNCTION
ENTER FUNCTION NUMBER (999 TO SEE LIST):
999
------------------------------------------------------------------------

FUNC. NO.    FUNC. NAME

   1      SEAT BOTTOM FDF
   2      SEAT BACK FDF
   3      STIFF SURFACES FDF
   4      DASH - FEMUR FDF
   5      FRONT DASH-FEMUR FDF
   6      DASH - TORSO FDF
   7      HEAD - WINDSHLD FDF
   8      COLUMN - BODY FDF
   9      STEERING COL E/A FDF
  10      SEGMENT-SEGMENT FDF
  11      HARNESS (CABLE) FDF
  12      HARNESS (LAP) FDF
  13      HARNESS (SHLDR) FDF
  14      HARNESS FDF
FORCE - DEFLECTION FUNCTION
ENTER FUNCTION NUMBER (999 TO SEE LIST):
10
------------------------------------------------------------------------
***** ALL SEGMENTS WILL HAVE THIS VALUE *****
FUNCTION SELECTION - SEGMENT NO.   1 ,  LT
ENERGY ABSORPTION (R) FUNCTION
ENTER 999 TO SEE LIST OR FUNCTION NUMBER :
999
------------------------------------------------------------------------

FUNC. NO.    FUNC. NAME

   1      SEAT BOTTOM R=0.625
   2      SEAT BACK R = 0.53
   3      STIFF SURF. R = 1.0
   4      DASH - FEMUR R=0.124
   5      DASH - TORSO R=0.133
   6      STEERING COLMN R=0.0
   7      SEG. - SEG. R-FACTOR
ENERGY ABSORPTION (R) FUNCTION
ENTER 999 TO SEE LIST OR FUNCTION NUMBER :
7
------------------------------------------------------------------------
***** ALL SEGMENTS WILL HAVE THIS VALUE *****
FUNCTION SELECTION - SEGMENT NO.   1 ,  LT
PERMANENT SET (G) FUNCTION
ENTER 999 TO SEE LIST OR FUNCTION NUMBER :
999
------------------------------------------------------------------------
```

```
FUNC. NO.     FUNC. NAME

   1       SEAT G = 0.08
   2       STIFF SURF. G = 0.88
   3       DASH - FEMUR G=0.809
   4       DASH - TORSO G=0.597
   5       SEG-SEG CONTCT G=0.0
PERMANENT SET (G) FUNCTION
ENTER 999 TO SEE LIST OR FUNCTION NUMBER :
5
------------------------------------------------------------------------
------------------------------------------------------------------------

FUNC. NO.     FUNC. NAME

   1       SEAT BOTTOM FDF
   2       SEAT BACK FDF
   3       STIFF SURFACES FDF
   4       DASH - FEMUR FDF
   5       FRONT DASH-FEMUR FDF
   6       DASH - TORSO FDF
   7       HEAD - WINDSHLD FDF
   8       COLUMN - BODY FDF
   9       STEERING COL E/A FDF
  10       SEGMENT-SEGMENT FDF
  11       HARNESS (CABLE) FDF
  12       HARNESS (LAP) FDF
  13       HARNESS (SHLDR) FDF
  14       HARNESS FDF
                                          FUNCTION SELECTION BY SEGMENT
                                             SEGMENT    FUNCTION NO.
                                               1    LT          10
                                               2    CT          10
                                               3    UT          10
                                               4    N           10
                                               5    H           10
                                               6    RUL         10
                                               7    RLL         10
                                               8    RF          10
                                               9    LUL         10
                                              10    LLL         10
                                              11    LF          10
                                              12    RUA         10
                                              13    RLA         10
                                              14    LUA         10
                                              15    LLA         10
 DO YOU WANT TO MAKE ANY CHANGES (YES OR NO)  n
------------------------------------------------------------------------
```

FUNC. NO.	FUNC. NAME
1	SEAT BOTTOM R=0.625
2	SEAT BACK R = 0.53
3	STIFF SURF. R = 1.0
4	DASH - FEMUR R=0.124
5	DASH - TORSO R=0.133
6	STEERING COLMN R=0.0
7	SEG. - SEG. R-FACTOR

FUNCTION SELECTION BY SEGMENT

SEGMENT		FUNCTION NO.
1	LT	7
2	CT	7
3	UT	7
4	N	7
5	H	7
6	RUL	7
7	RLL	7
8	RF	7
9	LUL	7
10	LLL	7
11	LF	7
12	RUA	7
13	RLA	7
14	LUA	7
15	LLA	7

DO YOU WANT TO MAKE ANY CHANGES (YES OR NO) n

FUNC. NO.	FUNC. NAME
1	SEAT G = 0.08
2	STIFF SURF. G = 0.88
3	DASH - FEMUR G=0.809
4	DASH - TORSO G=0.597
5	SEG-SEG CONTCT G=0.0

FUNCTION SELECTION BY SEGMENT

SEGMENT		FUNCTION NO.
1	LT	5
2	CT	5
3	UT	5
4	N	5
5	H	5
6	RUL	5
7	RLL	5
8	RF	5
9	LUL	5
10	LLL	5
11	LF	5
12	RUA	5
13	RLA	5
14	LUA	5
15	LLA	5

DO YOU WANT TO MAKE ANY CHANGES (YES OR NO) n

```
FUNCTION SELECTION
PLANE NO.   1  SEAT CUSHION


FORCE-DEFLECTION FUNCTION
ENTER FUNCTION NUMBER
(ENTER 0 FOR NO CONTACTS, 999 TO SEE LIST) :
1
--------------------------------------------------------------------------------
FUNCTION SELECTION
PLANE NO.   1  SEAT CUSHION
INERTIAL SPIKE FUNCTION
ENTER FUNCTION NUMBER
ENTER 0 FOR NO INERTIAL SPIKE, 999 TO SEE LIST) :
0
--------------------------------------------------------------------------------
FUNCTION SELECTION
PLANE NO.   1  SEAT CUSHION
ENERGY DISSIPATION (R) FUNCTION
ENTER FUNCTION NUMBER
(ENTER 999 TO SEE LIST) :
1
--------------------------------------------------------------------------------
FUNCTION SELECTION
PLANE NO.   1  SEAT CUSHION
PERMANENT SET (G) FUNCTION
ENTER FUNCTION NUMBER
(ENTER 999 TO SEE LIST) :
1
--------------------------------------------------------------------------------
FUNCTION SELECTION
PLANE NO.   1  SEAT CUSHION
FRICTION COEFFICIENT FUNCTION
ENTER FUNCTION NUMBER
(ENTER 999 TO SEE LIST) :
2
--------------------------------------------------------------------------------
FUNCTION SELECTION
PLANE NO.   2  SEAT BACK


FORCE-DEFLECTION FUNCTION
ENTER FUNCTION NUMBER
(ENTER 0 FOR NO CONTACTS, 999 TO SEE LIST) :
2
--------------------------------------------------------------------------------
FUNCTION SELECTION
PLANE NO.   2  SEAT BACK
INERTIAL SPIKE FUNCTION
ENTER FUNCTION NUMBER
ENTER 0 FOR NO INERTIAL SPIKE, 999 TO SEE LIST) :
0
--------------------------------------------------------------------------------
FUNCTION SELECTION
PLANE NO.   2  SEAT BACK
ENERGY DISSIPATION (R) FUNCTION
ENTER FUNCTION NUMBER
(ENTER 999 TO SEE LIST) :
2
--------------------------------------------------------------------------------
FUNCTION SELECTION
PLANE NO.   2  SEAT BACK
PERMANENT SET (G) FUNCTION
ENTER FUNCTION NUMBER
(ENTER 999 TO SEE LIST) :
1
```

```
FUNCTION SELECTION
PLANE NO.   2  SEAT BACK
FRICTION COEFFICIENT FUNCTION
ENTER FUNCTION NUMBER
(ENTER 999 TO SEE LIST) :
2
-----------------------------------------------------------------------
FUNCTION SELECTION
PLANE NO.   3  FLOOR BOARD


FORCE-DEFLECTION FUNCTION
ENTER FUNCTION NUMBER
(ENTER 0 FOR NO CONTACTS, 999 TO SEE LIST) :
3
-----------------------------------------------------------------------
FUNCTION SELECTION
PLANE NO.   3  FLOOR BOARD
INERTIAL SPIKE FUNCTION
ENTER FUNCTION NUMBER
ENTER 0 FOR NO INERTIAL SPIKE, 999 TO SEE LIST) :
0
-----------------------------------------------------------------------
FUNCTION SELECTION
PLANE NO.   3  FLOOR BOARD
ENERGY DISSIPATION (R) FUNCTION
ENTER FUNCTION NUMBER
(ENTER 999 TO SEE LIST) :
3
-----------------------------------------------------------------------
FUNCTION SELECTION
PLANE NO.   3  FLOOR BOARD
PERMANENT SET (G) FUNCTION
ENTER FUNCTION NUMBER
(ENTER 999 TO SEE LIST) :
2
-----------------------------------------------------------------------
FUNCTION SELECTION
PLANE NO.   3  FLOOR BOARD
FRICTION COEFFICIENT FUNCTION
ENTER FUNCTION NUMBER
(ENTER 999 TO SEE LIST) :
3
-----------------------------------------------------------------------
FUNCTION SELECTION
PLANE NO.   4  TOE BOARD


FORCE-DEFLECTION FUNCTION
ENTER FUNCTION NUMBER
(ENTER 0 FOR NO CONTACTS, 999 TO SEE LIST) :
3
-----------------------------------------------------------------------
FUNCTION SELECTION
PLANE NO.   4  TOE BOARD
INERTIAL SPIKE FUNCTION
ENTER FUNCTION NUMBER
ENTER 0 FOR NO INERTIAL SPIKE, 999 TO SEE LIST) :
0
```

```
FUNCTION SELECTION
PLANE NO.   4  TOE BOARD
ENERGY DISSIPATION (R) FUNCTION
ENTER FUNCTION NUMBER
(ENTER 999 TO SEE LIST) :
3
------------------------------------------------------------------------
FUNCTION SELECTION
PLANE NO.   4  TOE BOARD
PERMANENT SET (G) FUNCTION
ENTER FUNCTION NUMBER
(ENTER 999 TO SEE LIST) :
2
------------------------------------------------------------------------
FUNCTION SELECTION
PLANE NO.   4  TOE BOARD
FRICTION COEFFICIENT FUNCTION
ENTER FUNCTION NUMBER
(ENTER 999 TO SEE LIST) :
3
------------------------------------------------------------------------
FUNCTION SELECTION
PLANE NO.   5  WINDSHIELD


FORCE-DEFLECTION FUNCTION
ENTER FUNCTION NUMBER
(ENTER 0 FOR NO CONTACTS, 999 TO SEE LIST) :
0
PLANE SELECTED AS HAVING NO CONTACTS
------------------------------------------------------------------------
FUNCTION SELECTION
PLANE NO.   6  ROOF


FORCE-DEFLECTION FUNCTION
ENTER FUNCTION NUMBER
(ENTER 0 FOR NO CONTACTS, 999 TO SEE LIST) :
0
PLANE SELECTED AS HAVING NO CONTACTS
------------------------------------------------------------------------
FUNCTION SELECTION
PLANE NO.   7  DASH


FORCE-DEFLECTION FUNCTION
ENTER FUNCTION NUMBER
(ENTER 0 FOR NO CONTACTS, 999 TO SEE LIST) :
0
PLANE SELECTED AS HAVING NO CONTACTS
------------------------------------------------------------------------
FUNCTION SELECTION
PLANE NO.   8  KNEE BOLSTER


FORCE-DEFLECTION FUNCTION
ENTER FUNCTION NUMBER
(ENTER 0 FOR NO CONTACTS, 999 TO SEE LIST) :
0
PLANE SELECTED AS HAVING NO CONTACTS
```

FUNC. NO.	FUNC. NAME
1	SEAT BOTTOM FDF
2	SEAT BACK FDF
3	STIFF SURFACES FDF
4	DASH - FEMUR FDF
5	FRONT DASH-FEMUR FDF
6	DASH - TORSO FDF
7	HEAD - WINDSHLD FDF
8	COLUMN - BODY FDF
9	STEERING COL E/A FDF
10	SEGMENT-SEGMENT FDF
11	HARNESS (CABLE) FDF
12	HARNESS (LAP) FDF
13	HARNESS (SHLDR) FDF
14	HARNESS FDF

FUNCTION SELECTION BY PLANE

	PLANE	FUNCTION NO.
1	SEAT CUSHION	1
2	SEAT BACK	2
3	FLOOR BOARD	3
4	TOE BOARD	3
5	WINDSHIELD	0
6	ROOF	0
7	DASH	0
8	KNEE BOLSTER	0

DO YOU WANT TO MAKE ANY CHANGES (YES OR NO) n

FUNC. NO.	FUNC. NAME
1	HEAD - WINDSHLD SPIK

FUNCTION SELECTION BY PLANE

	PLANE	FUNCTION NO.
1	SEAT CUSHION	0
2	SEAT BACK	0
3	FLOOR BOARD	0
4	TOE BOARD	0
5	WINDSHIELD	0
6	ROOF	0
7	DASH	0
8	KNEE BOLSTER	0

DO YOU WANT TO MAKE ANY CHANGES (YES OR NO) n

FUNC. NO.	FUNC. NAME
1	SEAT BOTTOM R=0.625
2	SEAT BACK R = 0.53
3	STIFF SURF. R = 1.0
4	DASH - FEMUR R=0.124
5	DASH - TORSO R=0.133
6	STEERING COLMN R=0.0
7	SEG. - SEG. R-FACTOR

FUNCTION SELECTION BY PLANE

	PLANE	FUNCTION NO.
1	SEAT CUSHION	1
2	SEAT BACK	2
3	FLOOR BOARD	3
4	TOE BOARD	3
5	WINDSHIELD	0
6	ROOF	0
7	DASH	0
8	KNEE BOLSTER	0

DO YOU WANT TO MAKE ANY CHANGES (YES OR NO) n

```
FUNC. NO.    FUNC. NAME

   1      SEAT G = 0.08
   2      STIFF SURF. G = 0.88
   3      DASH - FEMUR G=0.809
   4      DASH - TORSO G=0.597
   5      SEG-SEG CONTCT G=0.0

                                   FUNCTION SELECTION BY PLANE
                                      PLANE      FUNCTION NO.
                                   1  SEAT CUSHION            1
                                   2  SEAT BACK               1
                                   3  FLOOR BOARD             2
                                   4  TOE BOARD               2
                                   5  WINDSHIELD              0
                                   6  ROOF                    0
                                   7  DASH                    0
                                   8  KNEE BOLSTER            0
DO YOU WANT TO MAKE ANY CHANGES (YES OR NO)  n
```

```
FUNC. NO.    FUNC. NAME

   1      FRICTION MU=1.0
   2      FRICTION MU = 0.75
   3      FRICTION MU=0.5
   4      HARNESS MU = 0.2
   5      HARNESS MU = 0.1
   6      CONSTANT, F=0.0

                                   FUNCTION SELECTION BY PLANE
                                      PLANE      FUNCTION NO.
                                   1  SEAT CUSHION            2
                                   2  SEAT BACK               2
                                   3  FLOOR BOARD             3
                                   4  TOE BOARD               3
                                   5  WINDSHIELD              0
                                   6  ROOF                    0
                                   7  DASH                    0
                                   8  KNEE BOLSTER            0
DO YOU WANT TO MAKE ANY CHANGES (YES OR NO)  n
```

```
----------------------------------------------------------------------------
                                          SEGMENT NO.   TITLE
                                               1          LT
                                               2          CT
                                               3          UT
                                               4          N
                                               5          H
                                               6          RUL
                                               7          RLL
                                               8          RF
                                               9          LUL
                                              10          LLL
                                              11          LF
                                              12          RUA
                                              13          RLA
                                              14          LUA
                                              15          LLA
PLANE CONTACT SELECTION
ENTER NO. OF SEGMENTS CONTACTING PLANE  1
SEAT CUSHION          :
3
ENTER SEGMENT NOS. FOR CONTACT WITH THIS PLANE
CONTACT NO.  1
INPUT SEGMENT NO. : 1
CONTACT NO.  2
INPUT SEGMENT NO. : 6
CONTACT NO.  3
INPUT SEGMENT NO. : 9
----------------------------------------------------------------------------
                                          SEGMENT NO.   TITLE
                                               1          LT
                                               2          CT
                                               3          UT
                                               4          N
                                               5          H
                                               6          RUL
                                               7          RLL
                                               8          RF
                                               9          LUL
                                              10          LLL
                                              11          LF
                                              12          RUA
                                              13          RLA
                                              14          LUA
                                              15          LLA
PLANE CONTACT SELECTION
ENTER NO. OF SEGMENTS CONTACTING PLANE  2
SEAT BACK             :
3
ENTER SEGMENT NOS. FOR CONTACT WITH THIS PLANE
CONTACT NO.  1
INPUT SEGMENT NO. : 1
CONTACT NO.  2
INPUT SEGMENT NO. : 2
CONTACT NO.  3
INPUT SEGMENT NO. : 3
```

SEGMENT NO.	TITLE
1	LT
2	CT
3	UT
4	N
5	H
6	RUL
7	RLL
8	RF
9	LUL
10	LLL
11	LF
12	RUA
13	RLA
14	LUA
15	LLA

```
PLANE CONTACT SELECTION
ENTER NO. OF SEGMENTS CONTACTING PLANE  3
FLOOR BOARD            :
2
ENTER SEGMENT NOS. FOR CONTACT WITH THIS PLANE
CONTACT NO.  1
INPUT SEGMENT NO. : 8
CONTACT NO.  2
INPUT SEGMENT NO. : 11
```

SEGMENT NO.	TITLE
1	LT
2	CT
3	UT
4	N
5	H
6	RUL
7	RLL
8	RF
9	LUL
10	LLL
11	LF
12	RUA
13	RLA
14	LUA
15	LLA

```
PLANE CONTACT SELECTION
ENTER NO. OF SEGMENTS CONTACTING PLANE  4
TOE BOARD              :
2
ENTER SEGMENT NOS. FOR CONTACT WITH THIS PLANE
CONTACT NO.  1
INPUT SEGMENT NO. : 8
CONTACT NO.  2
INPUT SEGMENT NO. : 11
```

```
------------------------------------------------------------------
                                              SEGMENT NO.   TITLE
                                                   1          LT
                                                   2          CT
                                                   3          UT
                                                   4          N
                                                   5          H
                                                   6          RUL
                                                   7          RLL
                                                   8          RF
                                                   9          LUL
                                                  10          LLL
                                                  11          LF
                                                  12          RUA
                                                  13          RLA
                                                  14          LUA
                                                  15          LLA
PLANE CONTACT SELECTION
ENTER NO. OF SEGMENTS CONTACTING PLANE  5
WINDSHIELD            :
0
NO CONTACTS ALLOWED FOR THIS PLANE
------------------------------------------------------------------
                                              SEGMENT NO.   TITLE
                                                   1          LT
                                                   2          CT
                                                   3          UT
                                                   4          N
                                                   5          H
                                                   6          RUL
                                                   7          RLL
                                                   8          RF
                                                   9          LUL
                                                  10          LLL
                                                  11          LF
                                                  12          RUA
                                                  13          RLA
                                                  14          LUA
                                                  15          LLA
PLANE CONTACT SELECTION
ENTER NO. OF SEGMENTS CONTACTING PLANE  6
ROOF                  :
0
NO CONTACTS ALLOWED FOR THIS PLANE
------------------------------------------------------------------
                                              SEGMENT NO.   TITLE
                                                   1          LT
                                                   2          CT
                                                   3          UT
                                                   4          N
                                                   5          H
                                                   6          RUL
                                                   7          RLL
                                                   8          RF
                                                   9          LUL
                                                  10          LLL
                                                  11          LF
                                                  12          RUA
                                                  13          RLA
                                                  14          LUA
                                                  15          LLA
PLANE CONTACT SELECTION
ENTER NO. OF SEGMENTS CONTACTING PLANE  7
DASH                  :
0
NO CONTACTS ALLOWED FOR THIS PLANE
```

```
                                                      SEGMENT NO.   TITLE
                                                           1          LT
                                                           2          CT
                                                           3          UT
                                                           4          N
                                                           5          H
                                                           6          RUL
                                                           7          RLL
                                                           8          RF
                                                           9          LUL
                                                          10          LLL
                                                          11          LF
                                                          12          RUA
                                                          13          RLA
                                                          14          LUA
                                                          15          LLA
PLANE CONTACT SELECTION
ENTER NO. OF SEGMENTS CONTACTING PLANE  8
KNEE BOLSTER          :
0
NO CONTACTS ALLOWED FOR THIS PLANE
----------------------------------------------------------------------
   PLANE                        SEGMENT CONTACTS
NO.     TITLE             NO.          SEGMENTS

 1 SEAT CUSHION            3:  1- LT ,  6- RUL,  9- LUL,
 2 SEAT BACK               3:  1- LT ,  2- CT ,  3- UT ,
 3 FLOOR BOARD             2:  8- RF , 11- LF ,
 4 TOE BOARD               2:  8- RF , 11- LF ,
 5 WINDSHIELD              0:
 6 ROOF                    0:
 7 DASH                    0:
 8 KNEE BOLSTER            0:
DO YOU WISH TO MODIFY ANY CONTACTS (YES OR NO) ?
n
DO YOU WISH TO SPECIFY ANY SEGMENT-SEGMENT CONTACTS (YES OR NO) ?
y
----------------------------------------------------------------------
                                                      SEGMENT NO.   TITLE
                                                           1          LT
                                                           2          CT
                                                           3          UT
                                                           4          N
                                                           5          H
                                                           6          RUL
                                                           7          RLL
                                                           8          RF
                                                           9          LUL
                                                          10          LLL
                                                          11          LF
                                                          12          RUA
                                                          13          RLA
                                                          14          LUA
                                                          15          LLA

SEGMENT CONTACT SELECTION
ENTER NO. OF SEGMENTS CONTACTING SEGMENT  1
    LT  :
0
```

SEGMENT NO.	TITLE
1	LT
2	CT
3	UT
4	N
5	H
6	RUL
7	RLL
8	RF
9	LUL
10	LLL
11	LF
12	RUA
13	RLA
14	LUA
15	LLA

SEGMENT CONTACT SELECTION
ENTER NO. OF SEGMENTS CONTACTING SEGMENT 2
CT :
0

SEGMENT NO.	TITLE
1	LT
2	CT
3	UT
4	N
5	H
6	RUL
7	RLL
8	RF
9	LUL
10	LLL
11	LF
12	RUA
13	RLA
14	LUA
15	LLA

SEGMENT CONTACT SELECTION
ENTER NO. OF SEGMENTS CONTACTING SEGMENT 3
UT :
0

SEGMENT NO.	TITLE
1	LT
2	CT
3	UT
4	N
5	H
6	RUL
7	RLL
8	RF
9	LUL
10	LLL
11	LF
12	RUA
13	RLA
14	LUA
15	LLA

SEGMENT CONTACT SELECTION
ENTER NO. OF SEGMENTS CONTACTING SEGMENT 4
N :
0

SEGMENT NO.	TITLE
1	LT
2	CT
3	UT
4	N
5	H
6	RUL
7	RLL
8	RF
9	LUL
10	LLL
11	LF
12	RUA
13	RLA
14	LUA
15	LLA

```
SEGMENT CONTACT SELECTION
ENTER NO. OF SEGMENTS CONTACTING SEGMENT  5
    H   :
0
```

SEGMENT NO.	TITLE
1	LT
2	CT
3	UT
4	N
5	H
6	RUL
7	RLL
8	RF
9	LUL
10	LLL
11	LF
12	RUA
13	RLA
14	LUA
15	LLA

```
SEGMENT CONTACT SELECTION
ENTER NO. OF SEGMENTS CONTACTING SEGMENT  6
    RUL :
2
ENTER SEGMENT NOS. FOR CONTACT WITH THIS SEGMENT
CONTACT NO.  1
INPUT SEGMENT NO. : 9
CONTACT NO.  2
INPUT SEGMENT NO. : 13
```

```
                                               SEGMENT NO.   TITLE
                                                   1          LT
                                                   2          CT
                                                   3          UT
                                                   4          N
                                                   5          H
                                                   6          RUL
                                                   7          RLL
                                                   8          RF
                                                   9          LUL
                                                  10          LLL
                                                  11          LF
                                                  12          RUA
                                                  13          RLA
                                                  14          LUA
                                                  15          LLA
SEGMENT CONTACT SELECTION
ENTER NO. OF SEGMENTS CONTACTING SEGMENT  7
    RLL :
2
ENTER SEGMENT NOS. FOR CONTACT WITH THIS SEGMENT
CONTACT NO.  1
INPUT SEGMENT NO. : 10
CONTACT NO.  2
INPUT SEGMENT NO. : 11
```

```
                                               SEGMENT NO.   TITLE
                                                   1          LT
                                                   2          CT
                                                   3          UT
                                                   4          N
                                                   5          H
                                                   6          RUL
                                                   7          RLL
                                                   8          RF
                                                   9          LUL
                                                  10          LLL
                                                  11          LF
                                                  12          RUA
                                                  13          RLA
                                                  14          LUA
                                                  15          LLA
SEGMENT CONTACT SELECTION
ENTER NO. OF SEGMENTS CONTACTING SEGMENT  8
    RF  :
2
ENTER SEGMENT NOS. FOR CONTACT WITH THIS SEGMENT
CONTACT NO.  1
INPUT SEGMENT NO. : 10
CONTACT NO.  2
INPUT SEGMENT NO. : 11
```

```
                                            SEGMENT NO.   TITLE
                                                 1         LT
                                                 2         CT
                                                 3         UT
                                                 4         N
                                                 5         H
                                                 6         RUL
                                                 7         RLL
                                                 8         RF
                                                 9         LUL
                                                10         LLL
                                                11         LF
                                                12         RUA
                                                13         RLA
                                                14         LUA
                                                15         LLA
SEGMENT CONTACT SELECTION
ENTER NO. OF SEGMENTS CONTACTING SEGMENT  9
    LUL :
1
ENTER SEGMENT NOS. FOR CONTACT WITH THIS SEGMENT
CONTACT NO.  1
INPUT SEGMENT NO. : 15
--------------------------------------------------------------------------
                                            SEGMENT NO.   TITLE
                                                 1         LT
                                                 2         CT
                                                 3         UT
                                                 4         N
                                                 5         H
                                                 6         RUL
                                                 7         RLL
                                                 8         RF
                                                 9         LUL
                                                10         LLL
                                                11         LF
                                                12         RUA
                                                13         RLA
                                                14         LUA
                                                15         LLA
SEGMENT CONTACT SELECTION
ENTER NO. OF SEGMENTS CONTACTING SEGMENT 10
    LLL :
0
--------------------------------------------------------------------------
                                            SEGMENT NO.   TITLE
                                                 1         LT
                                                 2         CT
                                                 3         UT
                                                 4         N
                                                 5         H
                                                 6         RUL
                                                 7         RLL
                                                 8         RF
                                                 9         LUL
                                                10         LLL
                                                11         LF
                                                12         RUA
                                                13         RLA
                                                14         LUA
                                                15         LLA
SEGMENT CONTACT SELECTION
ENTER NO. OF SEGMENTS CONTACTING SEGMENT 11
    LF  :
0
```

SEGMENT NO.	TITLE
1	LT
2	CT
3	UT
4	N
5	H
6	RUL
7	RLL
8	RF
9	LUL
10	LLL
11	LF
12	RUA
13	RLA
14	LUA
15	LLA

SEGMENT CONTACT SELECTION
ENTER NO. OF SEGMENTS CONTACTING SEGMENT 12
    RUA :
0

SEGMENT NO.	TITLE
1	LT
2	CT
3	UT
4	N
5	H
6	RUL
7	RLL
8	RF
9	LUL
10	LLL
11	LF
12	RUA
13	RLA
14	LUA
15	LLA

SEGMENT CONTACT SELECTION
ENTER NO. OF SEGMENTS CONTACTING SEGMENT 13
    RLA :
0

SEGMENT NO.	TITLE
1	LT
2	CT
3	UT
4	N
5	H
6	RUL
7	RLL
8	RF
9	LUL
10	LLL
11	LF
12	RUA
13	RLA
14	LUA
15	LLA

SEGMENT CONTACT SELECTION
ENTER NO. OF SEGMENTS CONTACTING SEGMENT 14
    LUA :
0

SEGMENT NO.	TITLE
1	LT
2	CT
3	UT
4	N
5	H
6	RUL
7	RLL
8	RF
9	LUL
10	LLL
11	LF
12	RUA
13	RLA
14	LUA
15	LLA

SEGMENT CONTACT SELECTION
ENTER NO. OF SEGMENTS CONTACTING SEGMENT 15
LLA :
0

SEGMENT NO.	SEGMENT TITLE	SEGMENT CONTACTS NO.	SEGMENTS
1	LT	0:	
2	CT	0:	
3	UT	0:	
4	N	0:	
5	H	0:	
6	RUL	2:	9- LUL, 13- RLA,
7	RLL	2:	10- LLL, 11- LF ,
8	RF	2:	10- LLL, 11- LF ,
9	LUL	1:	15- LLA,
10	LLL	0:	
11	LF	0:	
12	RUA	0:	
13	RLA	0:	
14	LUA	0:	
15	LLA	0:	

DO YOU WISH TO MODIFY ANY CONTACTS (YES OR NO) ?
n

FUNCTION SELECTION - SEGMENT NO. 6 , RUL
FRICTION COEFFICIENT (C) FUNCTION
ENTER FUNCTION NUMBER (999 TO SEE LIST):
3

FUNCTION SELECTION - SEGMENT NO. 7 , RLL
FRICTION COEFFICIENT (C) FUNCTION
ENTER FUNCTION NUMBER (999 TO SEE LIST):
3

FUNCTION SELECTION - SEGMENT NO. 8 , RF
FRICTION COEFFICIENT (C) FUNCTION
ENTER FUNCTION NUMBER (999 TO SEE LIST):
3

FUNCTION SELECTION - SEGMENT NO. 9 , LUL
FRICTION COEFFICIENT (C) FUNCTION
ENTER FUNCTION NUMBER (999 TO SEE LIST):
3

```
------------------------------------------------------------------------
------------------------------------------------------------------------

FUNC. NO.     FUNC. NAME

    1      FRICTION MU=1.0
    2      FRICTION MU = 0.75
    3      FRICTION MU=0.5
    4      HARNESS MU = 0.2
    5      HARNESS MU = 0.1
    6      CONSTANT, F=0.0
                                            FUNCTION SELECTION BY SEGMENT
                                      SEGMENT     FUNCTION NO.
                                                  1   LT             0
                                                  2   CT             0
                                                  3   UT             0
                                                  4   N              0
                                                  5   H              0
                                                  6   RUL            3
                                                  7   RLL            3
                                                  8   RF             3
                                                  9   LUL            3
                                                 10   LLL            0
                                                 11   LF             0
                                                 12   RUA            0
                                                 13   RLA            0
                                                 14   LUA            0
                                                 15   LLA            0
DO YOU WANT TO MAKE ANY CHANGES (YES OR NO)  n
------------------------------------------------------------------------
Stop - Program terminated.

C:\ATB\UCP>
```

```
C:\ATB\UCP>ndeck3
THE DEFAULT RESPONSE TO QUESTIONS IN THIS PROGRAM IS
<YES>.  A <CR>, Y, OR YES RESPONSE WILL BE
INTERPRETED AS AN AFFIRMATIVE RESPONSE.

FOR A NEGATIVE RESPONSE, YOU MUST ENTER "N" OR "n"

----------------------------------------------------------------------
INPUT FOR THE DEFAULT OPTION HAS BEEN GENERATED
DO YOU ACCEPT THE DEFAULT OPTION? <YES>
n
INPUT DATA WILL BE LISTED FOR ENTRY CORRECTION
IS THIS O.K. ? <YES>
y
----------------------------------------------------------------------
SEGMENT LINEAR ACCELERATIONS
SEGMENT NO.                LOCATION(X,Y,Z)
     5                .000        .000        .000
     3                .000        .000        .000
     1                .000        .000        .000
     8                .000        .000        .000
    11                .000        .000        .000
    16                .000        .000        .000
DO YOU ACCEPT THESE INPUTS ? <YES>
IF NOT, THE INPUTS MAY BE RESPECIFIED
y
----------------------------------------------------------------------
SEGMENT LINEAR VELOCITIES
SEGMENT NO.                LOCATION(X,Y,Z)
     5                .000        .000        .000
     3                .000        .000        .000
     1                .000        .000        .000
     8                .000        .000        .000
DO YOU ACCEPT THESE INPUTS ? <YES>
IF NOT, THE INPUTS MAY BE RESPECIFIED
y
----------------------------------------------------------------------
SEGMENT LINEAR DISPLACEMENTS
SEGMENT NO.                LOCATION(X,Y,Z)
     5                .000        .000        .000
     3                .000        .000        .000
     1                .000        .000        .000
     8                .000        .000        .000
    11                .000        .000        .000
    16                .000        .000        .000
DO YOU ACCEPT THESE INPUTS ? <YES>
IF NOT, THE INPUTS MAY BE RESPECIFIED
y
----------------------------------------------------------------------
SEGMENT ANGULAR ACCELERATIONS
SEGMENT NO.
     5
     3
     1
DO YOU ACCEPT THESE INPUTS ? <YES>
IF NOT, THE INPUTS MAY BE RESPECIFIED
y
----------------------------------------------------------------------
```

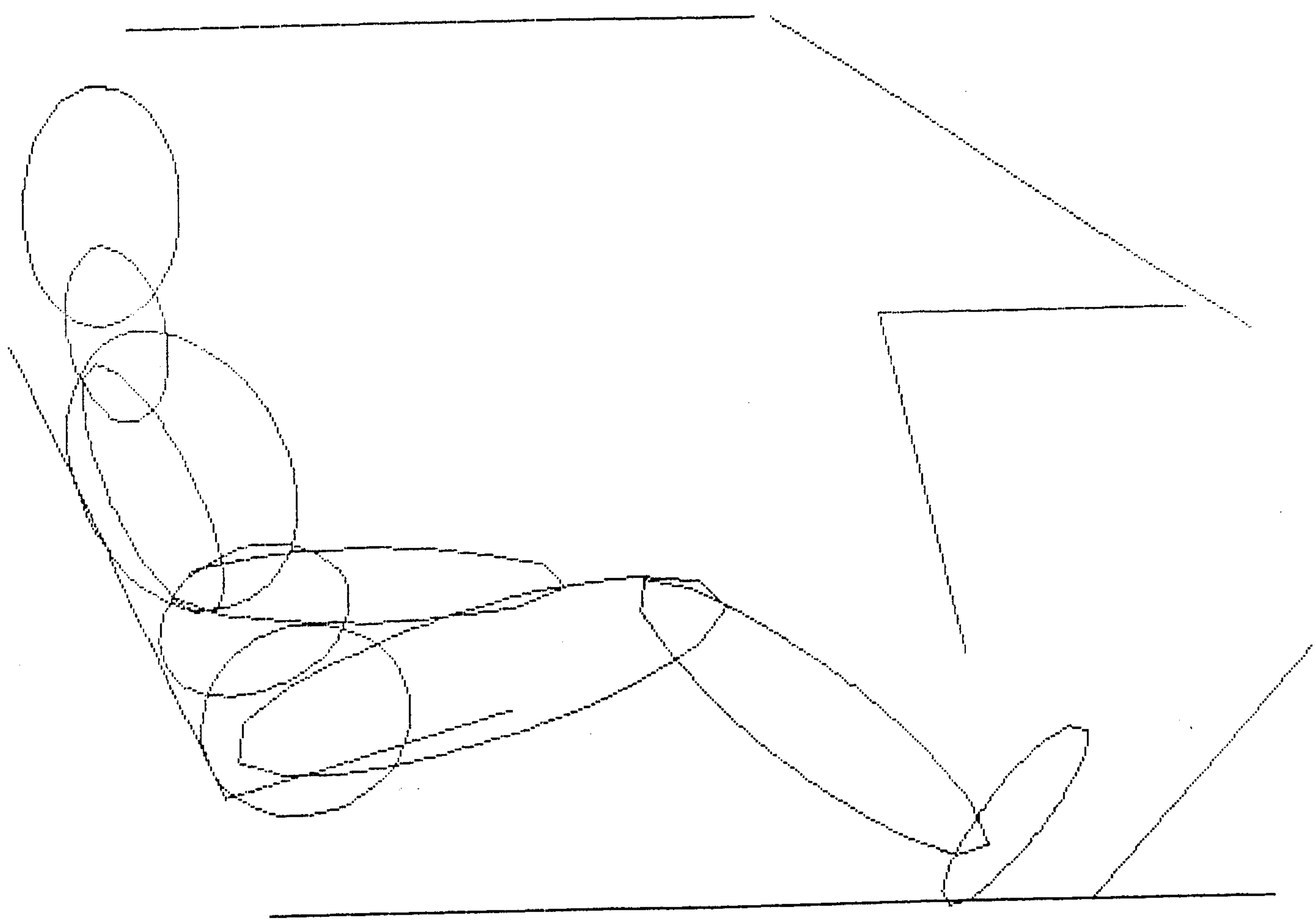
```
SEGMENT ANGULAR VELOCITIES
SEGMENT NO.
     5
     3
     1
DO YOU ACCEPT THESE INPUTS ? <YES>
IF NOT, THE INPUTS MAY BE RESPECIFIED
Y
-----------------------------------------------------------------------
SEGMENT ANGULAR DISPLACEMENTS
SEGMENT NO.
     5
     4
     3
     2
     1
     7
     9
     8
    10
DO YOU ACCEPT THESE INPUTS ? <YES>
IF NOT, THE INPUTS MAY BE RESPECIFIED
Y
-----------------------------------------------------------------------
JOINT PARAMETERS
JOINT NO.
     1
     2
     3
     4
     5
     6
     7
     8
     9
    10
    11
    12
    13
    14
DO YOU ACCEPT THESE INPUTS ? <YES>
IF NOT, THE INPUTS MAY BE RESPECIFIED
Y
-----------------------------------------------------------------------
Stop - Program terminated.

C:\ATB\UCP>
```

```
C:\ATB\UCP>NDECK4
THE DEFAULT RESPONSE TO QUESTIONS IN THIS PROGRAM IS
<YES>.  A <CR>, Y, OR YES RESPONSE WILL BE
INTERPRETED AS AN AFFIRMATIVE RESPONSE.  ANY OTHER
RESPONSE WILL BE INTERPRETED AS A NEGATIVE RESPONSE.

PLEASE WAIT - LOADING DATA FILES

---------------------------------------------------------------------------
CLEARANCE BETWEEN FOOT AND TOEBOARD IS ONE INCH
DO YOU WISH TO CHANGE THIS VALUE ?<YES>
N
---------------------------------------------------------------------------
DO YOU ACCEPT THIS INITIAL CONDITION ?
```



```
N
FOLLOWING OPTIONS ARE AVAILABLE

ENTER D FOR SEGMENT POSITION AND ORIENTATIONS
      E FOR ENTERING NEW POSITION AND ORIENTATIONS
      Q FOR QUITTING
D
---------------------------------------------------------------------------
```

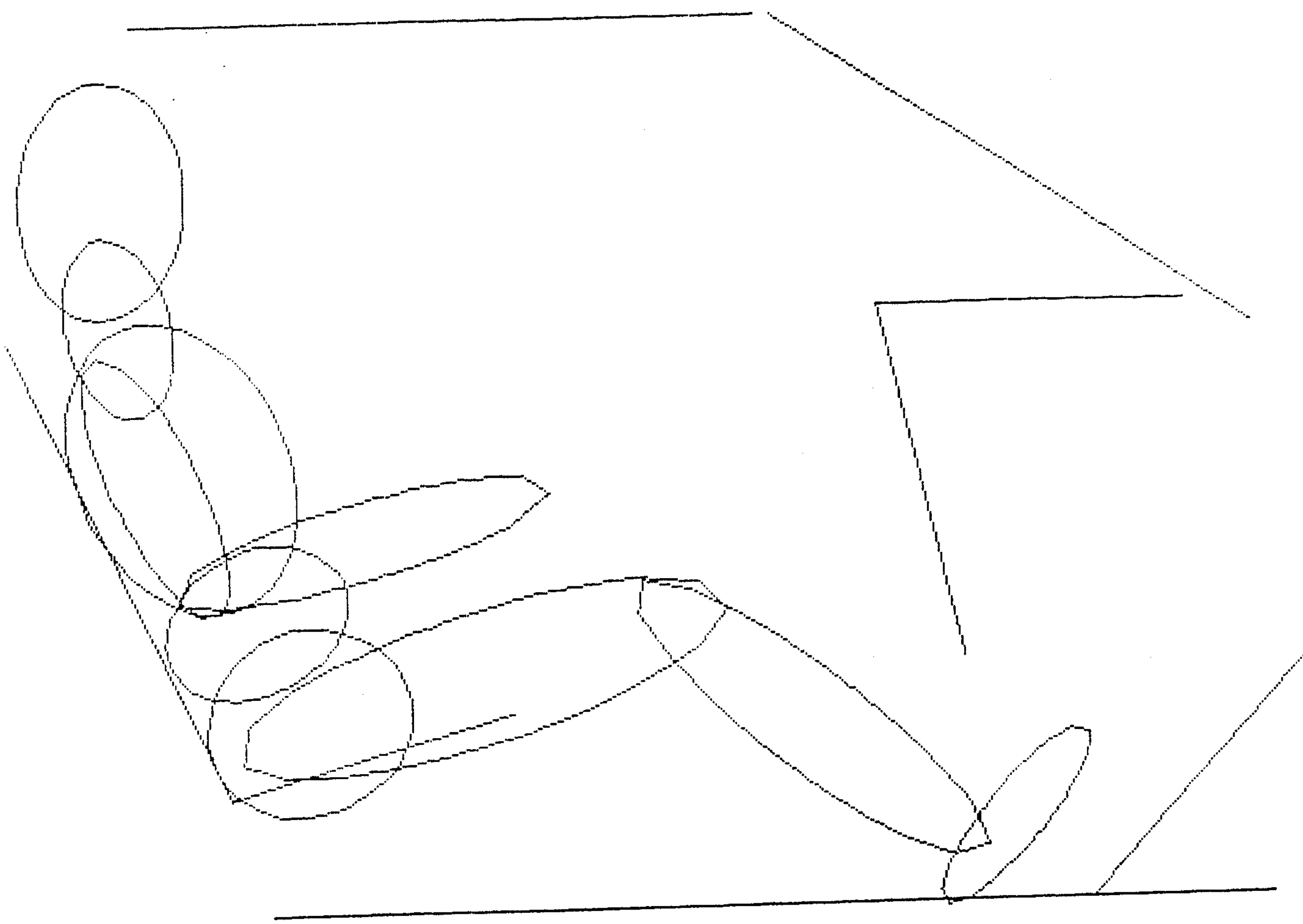
```
NO.       SEG POSITION                               SEG ORIENTATION
          X          Y          Z                YAW      PITCH       ROLL
 1      -6.22       .00      -4.93               .00      25.24        .00
 2      -7.31       .00      -9.50               .00      25.24        .00
 3     -12.08       .00     -16.06               .00      25.24        .00
 4     -14.94       .00     -24.31               .00      12.73        .00
 5     -13.67       .00     -28.92               .00        .00        .00
 6       1.55      4.31      -5.61               .00     106.78        .00
 7      16.45      5.37      -3.29               .00      50.69        .00
 8      27.55      4.95       1.58               .00     140.69        .00
 9       1.55     -4.31      -5.61               .00     106.78        .00
10      16.45     -5.37      -3.29               .00      50.69        .00
11      27.55     -4.95       1.58               .00     140.69        .00
12     -13.21      6.98     -14.70               .00      25.02        .00
13      -4.35      6.21     -10.30               .00      90.00        .00
14     -13.21     -6.98     -14.70               .00      25.02        .00
15      -4.35     -6.21     -10.30               .00      90.00        .00
---------------------------------------------------------------------------
FOLLOWING OPTIONS ARE AVAILABLE

ENTER D FOR SEGMENT POSITION AND ORIENTATIONS
      E FOR ENTERING NEW POSITION AND ORIENTATIONS
      Q FOR QUITTING
E
---------------------------------------------------------------------------
ENTER SEGMENT NO. TO BE CHANGED, TO STOP, ENTER 0
13
ENTER VARIABLE TYPE : 1. LINEAR
                      2. ANGULAR
2
ENTER THE VARIABLE TYPE INDEX
(1,2,3 FOR X,Y,Z OR YAW,PITCH,ROLL)
2
ENTER THE NEW VALUE OF THE VARIABLE
105
---------------------------------------------------------------------------
ENTER SEGMENT NO. TO BE CHANGED, TO STOP, ENTER 0
15
ENTER VARIABLE TYPE : 1. LINEAR
                      2. ANGULAR
2
ENTER THE VARIABLE TYPE INDEX
(1,2,3 FOR X,Y,Z OR YAW,PITCH,ROLL)
2
ENTER THE NEW VALUE OF THE VARIABLE
105
---------------------------------------------------------------------------
ENTER SEGMENT NO. TO BE CHANGED, TO STOP, ENTER 0
0
---------------------------------------------------------------------------
FOLLOWING OPTIONS ARE AVAILABLE

ENTER D FOR SEGMENT POSITION AND ORIENTATIONS
      E FOR ENTERING NEW POSITION AND ORIENTATIONS
      Q FOR QUITTING
D
---------------------------------------------------------------------------
NO.       SEG POSITION                               SEG ORIENTATION
          X          Y          Z                YAW      PITCH       ROLL
 1      -6.22       .00      -4.93               .00      25.24        .00
 2      -7.31       .00      -9.50               .00      25.24        .00
 3     -12.08       .00     -16.06               .00      25.24        .00
 4     -14.94       .00     -24.31               .00      12.73        .00
 5     -13.67       .00     -28.92               .00        .00        .00
 6       1.55      4.31      -5.61               .00     106.78        .00
 7      16.45      5.37      -3.29               .00      50.69        .00
 8      27.55      4.95       1.58               .00     140.69        .00
 9       1.55     -4.31      -5.61               .00     106.78        .00
10      16.45     -5.37      -3.29               .00      50.69        .00
11      27.55     -4.95       1.58               .00     140.69        .00
12     -13.21      6.98     -14.70               .00      25.02        .00
13      -4.74      6.21     -12.16               .00     105.00        .00
14     -13.21     -6.98     -14.70               .00      25.02        .00
15      -4.74     -6.21     -12.16               .00     105.00        .00
---------------------------------------------------------------------------
FOLLOWING OPTIONS ARE AVAILABLE

ENTER D FOR SEGMENT POSITION AND ORIENTATIONS
      E FOR ENTERING NEW POSITION AND ORIENTATIONS
      Q FOR QUITTING
Q
```

DO YOU ACCEPT THIS INITIAL CONDITION ?



Y

DATA DECK IS READY FOR JOB SUBMISSION
DATA FILE NAME IS : CVSINPT

Stop - Program terminated.

C:\ATB\UCP>

```
C:\ATB\USERCONF>atbposn
ENTER INPUT FILENAME, EXTENSION .ain IS ASSUMED:

driver
ENTER FILENAME FOR ALL OUTPUT FILES,
EXTENSIONS WILL BE ASSIGNED:

driver
ATBIV-4 COMPUTER MODEL - CEA VERSION
    ISTEP =    0       TIME =  0.00000 seconds

              ATB - INITIAL POSITIONING UTILITY

SEGMENT NUMBER 1  ( LT )   LINEAR POSITION    X=  -6.224  Y=    0.000   Z=  -4.92

SEG      YPR1     YPR2     YPR3     LINEAR ACCELERATION (G)       ANG ACCEL (RAD/S^2)
                                        X        Y        Z          X        Y        Z
 LT      0.00    25.24     0.00    -0.810    0.000   -0.140       0.0     70.0       0.
 CT      0.00    25.24     0.00     0.101    0.000    0.801       0.0   -141.0       0.
 UT      0.00    25.24     0.00    -0.241    0.000    0.148       0.0     18.5       0.
 N       0.00    12.73     0.00    -0.312    0.000    0.433       0.0    -61.2       0.
 H       0.00     0.00     0.00     0.151    0.000    0.513       0.0     -5.7       0.
 RUL     0.00   106.78     0.00    -0.501    0.056   -0.129      -2.7     -2.1       4.
 RLL     0.00    50.68     0.00     0.503    0.072   -1.047       2.4     75.5       4.
 RF      0.00   140.69     0.00     2.425   -0.012   -1.065    -155.3   -171.8     316.
 LUL     0.00   106.78     0.00    -0.501   -0.056   -0.129       2.7     -2.1      -4.
 LLL     0.00    50.68     0.00     0.503   -0.072   -1.047      -2.4     75.5      -4.
 LF      0.00   140.69     0.00     2.425    0.012   -1.065     155.3   -171.8    -316.
 RUA     0.00    25.02     0.00    -0.335    0.000    0.258       0.0      6.8      -0.
 RLA     0.00   105.00     0.00    -0.071   -0.002    0.739       0.2    -28.6       0.
 LUA     0.00    25.02     0.00    -0.335    0.000    0.258       0.0      6.8       0.
 LLA     0.00   105.00     0.00    -0.071    0.002    0.739      -0.2    -28.6       0.

Enter X,Y,Z,L,E,J,? or SEG & YPR (i.e. "RUL2") to change, 0 to END e


                          (INERTIAL)                                  (LOCAL)
                    U1 ARRAY (INCH/ SEC**2)                   U2 ARRAY (RAD/ SEC**2)
 ANGULAR ACCELERATIONS
SEGMENT              X          Y          Z              X           Y           Z
 1  LT         -309.49       0.00    -640.51           0.00      -32.26        0.00
 2  CT            0.00       0.00     386.09           0.00        0.00        0.00
 3  UT           19.90       0.00     376.80           0.00       -0.21        0.00
 4  N             0.00       0.00     386.09           0.00        0.00        0.00
 5  H             0.00       0.00     386.09           0.00        0.00        0.00
 6  RUL        -196.38       0.00    -265.32           0.00     -396.09      788.84
 7  RLL           0.00       0.00     386.09           0.00        0.00        0.00
 8  RF            0.00       0.00   -3322.52        -242.10    -1475.97      383.90
 9  LUL        -196.38       0.00    -265.32           0.00     -396.09     -788.84
10  LLL           0.00       0.00     386.09           0.00        0.00        0.00
11  LF            0.00       0.00   -3322.52         242.10    -1475.97     -383.90
12  RUA           0.00       0.00     386.09           0.00        0.00        0.00
13  RLA           0.00       0.00     386.09           0.00        0.00        0.00
14  LUA           0.00       0.00     386.09           0.00        0.00        0.00
15  LLA           0.00       0.00     386.09           0.00        0.00        0.00

Enter X,Y,Z,L,E,J,? or SEG & YPR (i.e. "RUL2") to change, 0 to END j
```

JOINT		IPIN	(INERTIAL) JOINT FORCES (LBS) X	Y	Z	(INERTIAL) JOINT TORQUES (INCH LBS) X	Y	Z	RELATIVE ANGULAR VEL (RAD/ SEC
1	P	0	-20.2	0.0	-66.5	0.0	0.0	0.0	0.0
2	W	0	-20.8	0.0	-65.4	0.0	0.0	0.0	0.0
3	NP	0	0.7	0.0	-6.0	0.0	0.0	0.0	0.0
4	HP	0	1.4	0.0	-4.6	0.0	0.0	0.0	0.0
5	RH	0	10.2	2.0	11.5	0.0	0.0	0.0	0.0
6	RK	1	10.1	0.6	-1.6	-16.2	0.0	0.1	0.0
7	RA	0	5.5	0.0	17.0	0.0	0.0	0.0	0.0
8	LH	0	10.2	-2.0	11.5	0.0	0.0	0.0	0.0
9	LK	1	10.1	-0.6	-1.6	16.2	0.0	-0.1	0.0
10	LA	0	5.5	0.0	17.0	0.0	0.0	0.0	0.0
11	RS	0	-1.9	0.0	-4.7	0.0	0.0	0.0	0.0
12	RE	1	-0.3	0.0	-1.2	0.3	0.0	-0.2	0.0
13	LS	0	-1.9	0.0	-4.7	0.0	0.0	0.0	0.0
14	LE	1	-0.3	0.0	-1.2	-0.3	0.0	0.2	0.0

Enter X,Y,Z,L,E,J,? or SEG & YPR (i.e. "RUL2") to change, 0 to END 1

ATB - INITIAL POSITIONING UTILITY

SEGMENT NUMBER 1 (LT) LINEAR POSITION X= -6.224 Y= 0.000 Z= -4.92

SEG	YPR1	YPR2	YPR3	LINEAR ACCELERATION (G) X	Y	Z	ANG ACCEL (RAD/S^2) X	Y	Z
LT	0.00	25.24	0.00	-0.810	0.000	-0.140	0.0	70.0	0.
CT	0.00	25.24	0.00	0.101	0.000	0.801	0.0	-141.0	0.
UT	0.00	25.24	0.00	-0.241	0.000	0.148	0.0	18.5	0.
N	0.00	12.73	0.00	-0.312	0.000	0.433	0.0	-61.2	0.
H	0.00	0.00	0.00	0.151	0.000	0.513	0.0	-5.7	0.
RUL	0.00	106.78	0.00	-0.501	0.056	-0.129	-2.7	-2.1	4.
RLL	0.00	50.68	0.00	0.503	0.072	-1.047	2.4	75.5	4.
RF	0.00	140.69	0.00	2.425	-0.012	-1.065	-155.3	-171.8	316.
LUL	0.00	106.78	0.00	-0.501	-0.056	-0.129	2.7	-2.1	-4.
LLL	0.00	50.68	0.00	0.503	-0.072	-1.047	-2.4	75.5	-4.
LF	0.00	140.69	0.00	2.425	0.012	-1.065	155.3	-171.8	-316.
RUA	0.00	25.02	0.00	-0.335	0.000	0.258	0.0	6.8	-0.
RLA	0.00	105.00	0.00	-0.071	-0.002	0.739	0.2	-28.6	0.
LUA	0.00	25.02	0.00	-0.335	0.000	0.258	0.0	6.8	0.
LLA	0.00	105.00	0.00	-0.071	0.002	0.739	-0.2	-28.6	0.

Enter X,Y,Z,L,E,J,? or SEG & YPR (i.e. "RUL2") to change, 0 to END rf2
Enter the NEW VALUE for (RF), YPR2 (Old Value = 140.685) 141

```
ISTEP =    0       TIME =  0.00000 seconds

ATB - INITIAL POSITIONING UTILITY

SEGMENT NUMBER 1  ( LT )   LINEAR POSITION    X=  -6.224  Y=   0.000  Z=  -4.92

SEG      YPR1     YPR2     YPR3     LINEAR ACCELERATION (G)      ANG ACCEL (RAD/S^2)
                                      X        Y        Z         X       Y       Z
 LT      0.00    25.24     0.00    -0.811   -0.001   -0.139      0.1     69.9     0.
 CT      0.00    25.24     0.00     0.101    0.000    0.802      0.1   -141.1     0.
 UT      0.00    25.24     0.00    -0.241    0.000    0.148      0.0     18.5     0.
 N       0.00    12.73     0.00    -0.312    0.000    0.434      0.0    -61.1     0.
 H       0.00     0.00     0.00     0.151    0.000    0.513      0.0     -5.7     0.
 RUL     0.00   106.78     0.00    -0.504    0.058   -0.130     -2.8     -1.9     5.
 RLL     0.00    50.68     0.00     0.508    0.071   -1.063      2.7     76.2     5.
 RF      0.00   141.00     0.00     2.444   -0.010   -1.115   -157.8   -169.6   319.
 LUL     0.00   106.78     0.00    -0.502   -0.057   -0.129      2.7     -2.1    -4.
 LLL     0.00    50.68     0.00     0.503   -0.072   -1.047     -2.4     75.5    -4.
 LF      0.00   140.69     0.00     2.425    0.012   -1.065    155.3   -171.8  -316.
 RUA     0.00    25.02     0.00    -0.335    0.000    0.258      0.0      6.8    -0.
 RLA     0.00   105.00     0.00    -0.071   -0.002    0.739      0.2    -28.6     0.
 LUA     0.00    25.02     0.00    -0.335    0.000    0.258      0.0      6.8     0.
 LLA     0.00   105.00     0.00    -0.071    0.002    0.739     -0.2    -28.6     0.

Enter X,Y,Z,L,E,J,? or SEG & YPR (i.e. "RUL2") to change, 0 to END rf2
Enter the NEW VALUE for ( RF ), YPR2 (Old Value =   141.000) 140
   ISTEP =    0       TIME =  0.00000 seconds

ATB - INITIAL POSITIONING UTILITY

SEGMENT NUMBER 1  ( LT )   LINEAR POSITION    X=  -6.224  Y=   0.000  Z=  -4.92

SEG      YPR1     YPR2     YPR3     LINEAR ACCELERATION (G)      ANG ACCEL (RAD/S^2)
                                      X        Y        Z         X       Y       Z
 LT      0.00    25.24     0.00    -0.809    0.002   -0.141     -0.2     70.2    -0.
 CT      0.00    25.24     0.00     0.101    0.000    0.800     -0.2   -140.9     0.
 UT      0.00    25.24     0.00    -0.241    0.000    0.147      0.0     18.5     0.
 N       0.00    12.73     0.00    -0.312    0.000    0.433      0.0    -61.2     0.
 H       0.00     0.00     0.00     0.151    0.000    0.513      0.0     -5.7     0.
 RUL     0.00   106.78     0.00    -0.495    0.053   -0.126     -2.4     -2.7     3.
 RLL     0.00    50.68     0.00     0.490    0.074   -1.008      1.8     73.7     4.
 RF      0.00   140.00     0.00     2.378   -0.015   -0.955   -149.6   -175.9   310.
 LUL     0.00   106.78     0.00    -0.500   -0.056   -0.129      2.8     -2.1    -4.
 LLL     0.00    50.68     0.00     0.503   -0.073   -1.047     -2.5     75.4    -5.
 LF      0.00   140.69     0.00     2.425    0.012   -1.065    155.3   -171.8  -316.
 RUA     0.00    25.02     0.00    -0.335    0.000    0.258      0.0      6.8    -0.
 RLA     0.00   105.00     0.00    -0.071   -0.002    0.739      0.2    -28.6     0.
 LUA     0.00    25.02     0.00    -0.335    0.000    0.258      0.0      6.8     0.
 LLA     0.00   105.00     0.00    -0.071    0.002    0.739     -0.2    -28.6     0.

Enter X,Y,Z,L,E,J,? or SEG & YPR (i.e. "RUL2") to change, 0 to END x
Enter the NEW VALUE for LINEAR POSITION - X (Old Value =    -6.224) -7
```

```
ISTEP =    0       TIME =  0.00000 seconds

            ATB - INITIAL POSITIONING UTILITY

SEGMENT NUMBER 1  ( LT )   LINEAR POSITION   X=  -7.000  Y=   0.000  Z=  -4.92

SEG     YPR1    YPR2    YPR3    LINEAR ACCELERATION (G)    ANG ACCEL (RAD/S^2)
                                  X       Y       Z         X       Y       Z
 LT     0.00   25.24    0.00   -0.474   0.002  -0.035     -0.2    47.4    -0.
 CT     0.00   25.24    0.00    0.523   0.000   0.765     -0.2  -141.6     0.
 UT     0.00   25.24    0.00    0.095   0.000   0.143      0.0    23.5     0.
 N      0.00   12.73    0.00   -0.153   0.000   0.433      0.0   -38.8     0.
 H      0.00    0.00    0.00    0.154   0.000   0.489      0.0    -6.3     0.
 RUL    0.00  106.78    0.00   -0.309   0.144  -0.081     -6.7     5.8    18.
 RLL    0.00   50.68    0.00    0.546   0.066  -1.068     11.6    68.4    15.
 RF     0.00  140.00    0.00    2.327  -0.080  -0.928   -161.5  -177.6   282.
 LUL    0.00  106.78    0.00   -0.315  -0.146  -0.084      7.1     6.4   -19.
 LLL    0.00   50.68    0.00    0.559  -0.065  -1.107    -12.3    70.1   -16.
 LF     0.00  140.69    0.00    2.375   0.077  -1.038    167.2  -173.5  -288.
 RUA    0.00   25.02    0.00   -0.189  -0.002   0.340      0.1    -3.6     0.
 RLA    0.00  105.00    0.00   -0.084   0.000   0.787     -0.2   -24.3     0.
 LUA    0.00   25.02    0.00   -0.189   0.002   0.341     -0.1    -3.6    -0.
 LLA    0.00  105.00    0.00   -0.084   0.000   0.787      0.2   -24.3    -0.

Enter X,Y,Z,L,E,J,? or SEG & YPR (i.e. "RUL2") to change, 0 to END 0
File "GCARDS.TMP" contains REVISED position data

C:\ATB\USERCONF>
```

950131

Using ATB in Collision Reconstruction

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ABSTRACT

The Articulated Total Body (ATB) computer program, sometimes referred to as the Crash Victim Simulator (CVS), is a powerful tool to aid in studying occupant kinematics in motor vehicle collisions. There are many options available within the ATB/CVS model and associated utility programs, such as GEBOD, which allow an analyst to model specific collisions and occupants. This paper discusses ATB/CVS as a tool for use in collision reconstruction. Specific examples are presented in developing a crash pulse from vehicle simulation programs such as EDSMAC, SMAC, HVOSM, etc. Techniques are also presented for modelling other moveable objects within the occupant environment, such as a seat back, steering column, or intrusion into the occupant compartment. A series of programs to aid in setting up an ATB data file, the CAL-3D Users Convenience Package, is also discussed.

INTRODUCTION

The Articulated Total Body (ATB)[1]* computer program, also known as the Crash Victim Simulator (CVS), is a powerful simulation tool that can be used to study occupant kinematics in motor vehicle collisions. However, the ATB/CVS program is generic in nature; the simulation model can be used to model occupants in motor vehicle collision, occupants being ejected from military aircraft, and vehicle rollover kinematics, to name a few. This generic nature may complicate the setup of the model. There are so many options available, a casual user may not understand the options well enough to make a proper selection.

There are also many options that were introduced in earlier versions of the program that have been superseded, such as the seat belt being replaced by the harness belt. However, one of the goals in developing the ATB/CVS model has always been to maintain backward compatibility with previous data files. This then requires that the options which have been superseded be left in the code to ensure that older data files will still produce the same output.

Cards A - Date and run description, units of input and output, control of restart, integrator and optional output.

Cards B - Physical characteristics of the segments and joints.

Cards C - Description of the vehicle motion.

Cards D - Contact planes, belts, air bags, contact (hyper)ellipsoids, constraints, symmetry options, spring dampers, and prescribed forces and torques.

Cards E - Functions defining force-deflections, stress-strains, inertial spike, energy absorption factor, and friction coefficients.

Cards F - Allowed contacts among segments, planes, belts, airbags, contact (hyper)ellipsoids and harnesses.

Cards G - Initial orientations and velocities of the segments.

Cards H - Control of output of time history of selected segment motions, joint parameters, wind forces, joint forces and torques, total body properties, and injury criteria.

Cards I - Control information for plotter output.

Figure 1 - Outline of ATB input.

There is a subset of all these options which can be used to model occupants in automobile collisions without the burdensome task of understanding ALL the other options. The basic options used in defining the occupant as well as the vehicle motion will be discussed in this paper.Every ATB simulation, including those used to study occupant kinematics in a motor vehicle collisions, contains nine (9) groups of data, identified by card letters A through I, as shown in Figure 1. The input file describes the occupant, the motion of the vehicle, and the possible interactions between the occupant and the environment (typically the vehicle interior).

* Numbers in brackets designate references found at the end of the paper.

OCCUPANT DESCRIPTION

One of the tasks in setting up an ATB model is to define the parameters for the occupant. The occupant is typically divided into 15 or 17 body segments, as shown in Figure 2. The contact surface for each segment is modelled by an ellipsoid. The ellipsoid dimensions along with inertial properties are required for every segment. A computer program has been developed to aid a researcher in defining these parameters. The program is called GEBOD (GEnerator of BOdy Data)[2]. Version GEBODIII, was released in 1991, with version GEBODIII.1 as an update in April of 1993.

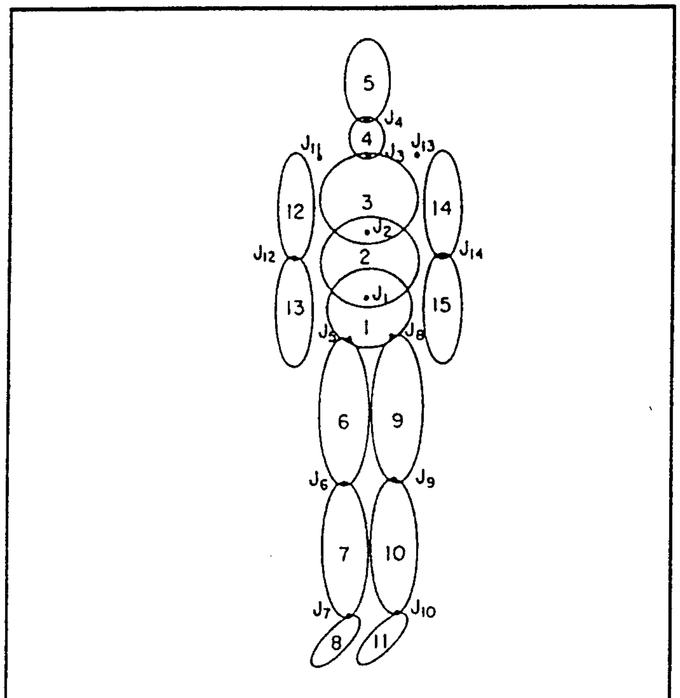

Figure 2 - ATB occupant segments.

The GEBOD program can be used to produce human or anthropomorphic test device (ATD) models for use in the ATB program. There are three different ATD types which can be produced; 1) sitting Hybrid III (50 %tile), 2) standing Hybrid III (50 %tile), and 3) Hybrid II (50 %tile). In addition, GEBOD can read a file with specific body dimensions supplied by the user. The program then uses these dimensions to generate the body segment descriptions. For human modelling, the program prompts the user for certain specific information regarding the human to model, such as gender, height, weight, etc., as shown in Figure 3. GEBOD then uses regression equations to approximate the required properties and produce a file in the format required by ATB.

Almost any size occupant can be modelled using GEBOD. Female height ranges from 1.446 to 1.830 meters(56.93 to 72.05 inches) and weight ranges from 378.1 to 889.7 newtons (85 to 200 lbs). There are similar ranges for the adult male occupant model, with the height ranging from 1.579 to 1.972 meters (62.17 to 77.64 inches) and the weight ranging from 524.9 to 1174.0 newtons (118 to 264 lbs). A child model is also available which permits input of age from 2 to 20 years old, with no distinction for gender.

```
PROGRAM GEBOD
GEBOD GENERATES BODY DESCRIPTION DATA
SUITABLE FOR INPUT TO THE ATB MODEL
PLEASE ENTER A DESCRIPTION OF THE SUBJECT (<60 CHARS.)
Female occupant, 62 inches - 110 lbs

ENTER FILENAME FOR ALL OUTPUT FILES,
EXTENSIONS WILL BE ASSIGNED:
sac-1

     1) CHILD (2 - 20 YEARS)
     2) ADULT HUMAN FEMALE
     3) ADULT HUMAN MALE
     4) USER-SUPPLIED BODY DIMENSIONS
     5) SITTING HYBRID III DUMMY (50%)
     6) STANDING HYBRID III DUMMY (50%)
     7) HYBRID II DUMMY (50%)

ENTER NUMBER CORRESPONDING TO DESIRED SUBJECT TYPE
2

     1) WEIGHT
     2) STANDING HEIGHT
     3) ALL OF THE ABOVE

ENTER NUMBER CORRESPONDING TO
PREDICTING DIMENSION(S) TO BE SUPPLIED
3

SELECT UNITS FOR WEIGHT
   1) LB.
   2) N.
   3) %-TILE
1

ENTER VALUE FOR WEIGHT
IN THE RANGE 85.00  , 200.0

SELECT UNITS FOR STANDING HEIGHT
   1) IN.
   2) M.
   3) %-TILE
1

ENTER VALUE FOR STANDING HEIGHT
IN THE RANGE 56.93  , 72.05

     1) FOREARM AND HAND COMBINED
     2) FOREARM AND HAND SEPARATED

ENTER THE NUMBER CORRESPONDING TO THE DESIRED
LOWER ARM SEGMENTATION
1

SELECT UNITS FOR OUTPUT
   1) ENGLSH
   2) METRIC
1
```

Figure 3 - GEBOD prompts.

Each data set produced by GEBOD must be checked for reasonable output data. The program uses a set of regression formulas, and sometimes occupant data is produced that is unreasonable . For example, Figure 4 shows two data sets produced for a small female; the moments of inertia for the center-torso (CT) are negative. Apparently, the regression formulas produce a curve fit which drops below zero for this property in this

small range of values. This problem has been corrected in version GEBODIV, which should be distributed in early 1995. Any output used from previous GEBOD runs modelling a small female should be reviewed carefully.

```
Female - 66 inches in height and 120 lbs

CRASH VICTIM PARAMETERS (3-D)

                              PRINCIPAL MOMENT OF INERTIA
 SEGMENT         WEIGHT              (LB-SEC**2-IN)
 I SYM PLOT      (LB. )          X         Y         Z
 1  LT    1      14.351     0.4332    0.2159    0.4541
 2  CT    2       2.869     0.0211   -0.0182    0.0041
 3  UT    3      32.011     1.9986    1.5555    1.1259

Female - 66 inches in height and 110 lbs

CRASH VICTIM PARAMETERS (3-D)

                               PRINCIPAL MOMENT OF INERTIA
 SEGMENT         WEIGHT              (LB-SEC**2-IN)
 I SYM PLOT      (LB. )          X         Y         Z
 1  LT    1      11.915     0.2882    0.0652    0.2191
 2  CT    2       2.197    -0.0138   -0.0480   -0.0568
 3  UT    3      29.540     1.7534    1.3643    0.9138
```

Figure 4 - Incorrect properties generated by GEBOD.

VEHICLE MOTION

The motion of the motor vehicle can be described using one of four options, as shown in Figure 5. For studying a specific collision, the user typically uses: Option 1 (half-sine wave deceleration) with a specified speed change; or Option 4 (spline fitted position, velocity, or deceleration) using results of a vehicle simulation program such as EDSMAC[3], SMAC[4], or HVOSM[5]. The method described herein utilizes the results of an EDSMAC simulation.

Once the vehicle simulation has been completed, the resulting position verses time data is used as input for the ATB program. The velocity or acceleration data may also be used, it simply depends on which data the user selects. For the simplest description of motion, the position and orientation data are the easiest to use.

The vehicle position data which is output from most simulation programs is in feet. This data must be converted to inches for input into the ATB program. The EDSMAC program stores the data in the output file in inches. EDSMAC then converts the data to feet for printout. A proprietary program has been written which will read the data in the EDSMAC output file and generate the input data for ATB. This utility program is used to quickly produce a data file containing the EDSMAC crash pulse, in ATB format. This data file is then inserted into the ATB input file using a file editor.

The spline fit routine produces a data look-up table of vehicle accelerations, either directly for acceleration entries or by differentiating position and velocity data. This table of acceleration data is then used by the program just as if the user had entered it using Option 3 (six degree-of-freedom deceleration). To clarify, no matter what type of data is input (position, velocity, or acceleration), the spline fit routine generates a table of acceleration data that is then used by the program integrator. The integration routines in the ATB model will then integrate the acceleration data in these tables to produce the velocity and position of the vehicle. The integration routines may not produce exactly the same position data as was supplied, depending on time steps of integration, type of integration, etc. This data can be checked using printed tables generated with the H-cards in ATB.

The H.1, H.3, H.4, and H.6 cards should be used to verify that the motion being produced by the ATB model is what the user expects and that the motion and accelerations of the vehicle are reasonable. The H-cards are used in the ATB input file to identify additional time history tables for any segments or joints. These tables may include linear acceleration (H.1), linear velocity (H.2), and linear displacement (H.3). The segment angular acceleration, velocity, and displacement are available on cards H.4, H.5, and H.6 respectively. Other cards (H.7 through H.10) are available for joint parameters, wind forces, joint forces and torques, and total body properties. The ATB program will also calculate the Head Injury Criteria (HIC), Head Severity Index (HSI) and Chest Severity Index (CSI) if desired, by using the H.11 cards.

Option 1: Half sine wave deceleration impulse (NATAB = 0)

Option 2: Tabular unidirectional deceleration (NATAB > 0)

Option 3: Six degree of freedom deceleration
(NATAB < 0 and LTYPE = 0)

Option 4: Spline fit position, velocity or deceleration data
(NATAB <0 and LTYPE > 0)

Figure 5 - Vehicle motion options in the ATB program.

One of the limitations of using Option 4 for specified vehicle motion is that only 101 data points may be entered. In order to model a 200 msec. collision, data points for every 2 msec. are output from EDSMAC. For a long ATB run, such as a rollover, longer time intervals may be used or other vehicle motion options are available in ATB.

One of the most important items to check is the calculated vehicle acceleration produced in the ATB model. Using the H.1 and H.4 cards the acceleration produced in the ATB model can be checked against the test data, or vehicle simulation data, to confirm that the approximate acceleration pulse is being produced. Similarly, when utilizing acceleration data for the vehicle motion data, the H.3 and H.6 cards should be used to confirm that the appropriate displacements are being produced during the model integration.

The ATB model assigns segment numbers to every object that can move plus one for the ground. Thus, with 15 occupant segments, the first vehicle is segment 16 (NSEG+1). Any other vehicles are numbered accordingly. Air bags are numbered next, then the ground is numbered as the highest segment number. Thus, the ground (NGRND) is equal to the number of occupant body segments (NSEG) plus the number of airbags (NBAG) plus the

number of vehicles (NVEH) plus 1. For the simplest case then, NSEG is 15 for the occupant body segments, NVEH is 16 and NGRND is 17. Note that NGRND can usually be referred to as segment number zero also.

The following section describes suggested values on the ATB C-cards when using a crash pulse generated by EDSMAC. The reader should have the ATB User's Guide [1] available to fully understand the variables and suggested input values. In order to use the position data, generated by EDSMAC, the C-cards should contain the following data:

Card C.1 - Appropriate title describing motion data.

Card C.2.a - All values should be blank, except:

NATAB - Negative value of the number of acceleration points to be produced, this includes one for the starting time. For example (-201) will produce 201 spline fitted data points describing the acceleration of the vehicle. The maximum number of data points produced is 501.

AT0 - First time point of spline fitted data, typically this would be 0.0 to produce a table that starts at 0. seconds.

ATD - Fixed time interval (in seconds) for spline fitted data. Typically this would be 0.001 or 0.002 to produce a table up to ABS(NATAB)*ATD seconds. For example, 200*0.001 would produce a table of spline fitted data every 1 msec. up to 0.200 seconds, while 100*0.002 would produce a table of data every 2 msec. up to 0.200 seconds.

I1 - Flag to indicate whether the prescribed motion is relative to the ground (0 - default), another segment (I1=2), or is relative to another segment, but with an inverse vector (I1=1). The inverse option is used to specify the motion of a reference system relative to the vehicle (useful when using accelerometer data).

I3 - The reference segment for the prescribed motion when the I1 flag is not zero. When using position data from a vehicle simulation, this should be zero to indicate that the positions are relative to the ground.

MSEG - The segment number associated with the prescribed motion. The primary vehicle must be the last motion specified, and MSEG must be zero for the primary vehicle. MSEG being zero specifies that this is the last motion data to be input.

Card C.2.b - All variables should be blank or zero except:

LTYPE - The type of data being input. For position data, LTYPE should be 1, for velocity data LTYPE=2, and for acceleration data, LTYPE=3.

LFIT - The degree of polynomial for spline fitting the input data. For position data, LFIT must be 2 or 3. Usually a value of 3 will produce acceptable results, but the second derivative (acceleration) should be checked by using the H.1 and H.4 cards.

NPTS - Number of data points supplied, the maximum number of data points is 101.

Card C.5 - The time, in seconds, for each data point along with the position, in inches, (X,Y,Z) and the orientation data, in degrees, (yaw, pitch, roll).

Figure 6 shows a partial output listing from the EDSMAC model of RICSAC case 6. The motion of the Volkswagen Rabbit, vehicle number 2, is modelled in this example.

The corresponding ATB input listing is shown in Figure 7. Recall that the output from the EDSMAC run is in feet, while the input required for the ATB model is in inches. The input listing shows the options for position input as described above.

RICSAC Case #6 Chevelle vs. Rabbit

Time Sec	X #2 ft	Y #2 ft	PSI #2 deg	V tot #2 ft/sec	U-vel #2 ft/sec	V-vel #2 ft/sec	PSI-dot #2 deg/sec
0.000	12.17	1.00	120.00	31.49	31.49	0.00	0.00
0.002	12.14	1.05	120.00	31.48	31.48	0.00	0.00
0.003	12.12	1.08	120.00	31.48	31.48	0.00	0.00
0.005	12.09	1.14	120.00	31.47	31.47	0.00	0.00
0.007	12.06	1.19	120.00	31.46	31.46	0.00	0.00
0.009	12.03	1.25	120.00	31.45	31.45	-0.00	0.01
0.010	12.01	1.27	120.00	31.45	31.45	-0.00	0.01
0.012	11.98	1.33	120.00	31.44	31.44	-0.01	0.01
0.014	11.95	1.38	120.00	31.42	31.42	-0.01	0.02
0.016	11.92	1.44	120.00	31.40	31.40	-0.02	0.03
0.018	11.88	1.49	120.00	31.38	31.38	-0.02	0.05
0.020	11.85	1.54	120.00	31.36	31.36	-0.03	0.08

Figure 6 - Partial EDSMAC output listing.

```
EDSMAC SIMULATION OUTPUT FOR VEH 2 IN RICSAC #6                              CARD C1
   0.     0.     0.     0.     0.     0.     0.     0.   -200    0. 0.001 0 0 0CARD C2A
    1      3    101                                                          CARD C2B
    .0000  146.0000   12.0000       0.0  120.0088       0.0       0.0
    .0020  145.6221   12.6545       0.0  120.0088       0.0       0.0
    .0030  145.4332   12.9817       0.0  120.0088       0.0       0.0
    .0050  145.0555   13.6359       0.0  120.0088       0.0       0.0
    .0070  144.6779   14.2899       0.0  120.0088       0.0       0.0
    .0090  144.3004   14.9438       0.0  120.0088       0.0       0.0
    .0100  144.1117   15.2707       0.0  120.0088       0.0       0.0
    .0120  143.7345   15.9242       0.0  120.0089       0.0       0.0
    .0140  143.3575   16.5776       0.0  120.0089       0.0       0.0
    .0160  142.9809   17.2306       0.0  120.0089       0.0       0.0
    .0180  142.6046   17.8833       0.0  120.0090       0.0       0.0
    .0200  142.2287   18.5357       0.0  120.0092       0.0       0.0
```

Figure 7 - Partial listing of ATB input file used in example run.

ADDITIONAL VEHICLES - In order to include the second vehicle from this EDSMAC run, a second "vehicle" segment must be defined. This vehicle will be referred to as a "secondary" vehicle, with the distinction being that the occupant of interest is in the "primary" vehicle. In the ATB data input file, there are many references to the "primary" vehicle and some variables will default to this segment, such as occupant reference systems for initial positioning.

The secondary vehicle does not need all the B-card information, as long as no other inertial segments will be attached to it . The exact motion will be specified on C-cards. By specifying the next available segment number (MSEG is set to NSEG+1), the ATB program sets up an additional segment. This segment has no inertial properties and only contact panels or ellipsoids can be attached to it. In this manner, the second vehicle from the EDSMAC run can be specified. A contact panel is attached to investigate the interaction of the occupant, in the primary vehicle, with the front, hood, side, etc. of the second vehicle. Figure 8 shows a partial listing of an ATB input file using this technique.

In this data file, the secondary vehicle is segment number 16, the primary vehicle is segment number 17, and the ground is segment number 18. The C-card section now contains two sets of motion data. The first set of C-cards is for the secondary vehicle,

```
   16     15        Largest adult female                                     CARD B.1
LT  1 31.001.44621.15071.9651 5.299 8.314 4.866 0.353 0.000 2.094   1      CARD B.2
              0.00  0.00   0.0
.....................................................................
.....................................................................
  0.01  0.01  0.01  0.00  0.00  0.00  0.10  0.10  0.10  0.00  0.00  0.00CARD B.6
EDSMAC SIMULATION OUTPUT FOR VEH 1 IN RICSAC #6 (ATB SECOND VEHICLE)     CARD C1
   0.     0.     0.     0.     0.     0.     0.     0.   -200    0. 0.001 0 016CARD C2A
    1      3    101                                                      CARD C2B
    .0000      .0000     .0000       0.0      .0000       0.0       0.0
    .2000   59.2789    4.6024       0.0   11.0669       0.0       0.0
EDSMAC SIMULATION OUTPUT FOR VEH 2 IN RICSAC #6                          CARD C1
   0.     0.     0.     0.     0.     0.     0.     0.   -200    0. 0.001 0 0 0CARD C2A
    1      3    101                                                      CARD C2B
    .0000  146.0000   12.0000       0.0  120.0088       0.0       0.0
    .2000  131.8055   66.8012       0.0  135.5376       0.0       0.0
    6      0      0      0      0      0      0      0      0      0      CARD D1
.....................................................................
.....................................................................
     1.000     1.000     1.000   0    0          0                       CARD G1A
  -12.0000  -13.0000  -13.3260                            0 17           CARD G2A
    0.0000   21.0000    0.0000                            3  2   1 17CARD G3A
.....................................................................
.....................................................................
    0.0000   90.0000    0.0000                            3  2   1 17CARD G3
    1  0 17            0.0          0.0          0.0                     CARD H1A
```

Figure 8 - Partial listing of ATB input file showing parameters used for "dummy" vehicle.

with MSEG equal to 16 on card C.2. The second set of C-cards contains motion data for the primary vehicle, with MSEG equal to zero on card C.2. Recall that MSEG being zero signals the end of the C-card section; thus the C-cards for the primary vehicle must be the last set of C-cards.

This type of ATB run is useful in studying the interaction between an occupant and the intruding structure of another vehicle. Care must be taken when modelling this type of collision using ATB with motion from a simulation such as EDSMAC. The simulation program is modelling a deformed vehicle while ATB does not model the vehicle deformation at all. Thus, when examining the interaction with the opposing vehicle, the panels used to define the vehicle must be correctly defined to model the deformation which the simulation is predicting. If this is not done, the striking vehicle will appear to intrude much further into the struck vehicle than the simulation is showing, and the results will not be correct.

In these situations, a dynamic crush pattern must be established. Additional vehicle panels are then used in the ATB model to depict the intrusion. A "secondary" vehicle is set up with the deformed panels attached to it. The motion for the panels is then defined by specifying the motion of this secondary vehicle. Then using the deformation pattern from EDSMAC (at the specified time from start of impact) and performing an iterative series of runs, the time of interaction between the occupant and the intruding vehicle can be confirmed.

OTHER MOVEABLE SEGMENTS - Using a similar technique of a "secondary" vehicle, other moveable interior components may be modelled. This technique involves setting up a "dummy" segment in the B-cards. Unlike the technique described above with the second vehicle from EDSMAC, another segment must be used. Any time a segment with inertial properties will be attached, a "dummy" segment must be used. This specification is required due to the chain setup of the ATB model. The model expects each segment identified in the B-cards to be connected to one of the previously defined segments. For example, the sixth segment specified by the B.2 cards is expected to be connected to one of the first five segments by some type of joint. Thus, if a seat back mass is defined as the sixteenth segment, then the ATB program expects it to be connected to one of the fifteen segments defined previously in the input data. There is a "null" joint option, but this indicates that the segment is not joined to anything, which is not the case for the seat back being modelled.

To achieve the appropriate setup, a "dummy" segment is defined as the sixteenth segment with a null joint, then the seat back, steering column, or other moveable segment is segment 17 and is attached to this dummy segment with the joint required. This dummy segment requires values for mass, moments of inertia, etc. on the B-cards. This segment will be used for reference only and will be rigidly attached to the primary vehicle, therefore the actual values used for inertia properties are not important. For simplicity, all the required values are set to unity (1.0). Blank cards are also required for the G.2 and G.3 cards because the dummy segment will be a reference segment.

The dummy segment is rigidly attached to the primary vehicle by specifying motion cards that lock the position throughout the simulation, as shown in Figure 9. By attaching the dummy segment at the vehicle c.g., the reference system stays the same as the primary vehicle. Note that the dummy segment could be attached at any location and at any rotation as required. The location and orientation of this dummy segment is an important consideration in simplifying subsequent references using position data of the other "linked" segments.

For the seat back model, a mass segment is defined with the appropriate seat back properties, and a contact plane is then attached to this seat back mass segment. The contact may be modelled using segment to segment modelling; however, a rectangular contact plane more accurately models the geometry of the seat back contact surface. The seat back mass segment is attached to the dummy segment with a hinge joint at the proper location on the B.3 cards, and the joint torque characteristics can then be defined either on the B.4a cards or on the E.7, F.5 cards. The ATB graphics output for a seat back model in a rear impact is shown in Figure 10.

When modelling a steering column, the lower column is attached to the dummy segment with a ball-and-socket joint. The upper column is attached to the lower column with a slip joint. The steering wheel and hub usually are then attached to the upper steering column using another ball-and-socket joint. The joint spring characteristics are defined on the B.4, B.5 cards using data from testing or other published data.

When setting up the ATB program to model vehicle intrusion or interior panel movement, the dummy segment is not necessary. In this case a second reference segment is defined, just like the EDSMAC example above. This reference segment can then be moved with respect to the primary vehicle by using position versus time data from the collision simulation or test data. This movement

```
LOCKED MASS FOR SEAT BACK REFERENCE                                    CARD C1
    0.    0.    0.    0.    0.    0.    0.    0.    -5    0.    2. 21816CARD C2A
    1     2     6                                                      CARD C2B
     .0000      .0000      .0000      0.0      .0000      0.0      0.0
    2.0000      .0000      .0000      0.0      .0000      0.0      0.0
    4.0000      .0000      .0000      0.0      .0000      0.0      0.0
    6.0000      .0000      .0000      0.0      .0000      0.0      0.0
    8.0000      .0000      .0000      0.0      .0000      0.0      0.0
   10.0000      .0000      .0000      0.0      .0000      0.0      0.0
```

Figure 9 - ATB C-cards used to lock "dummy" vehicle to primary vehicle.

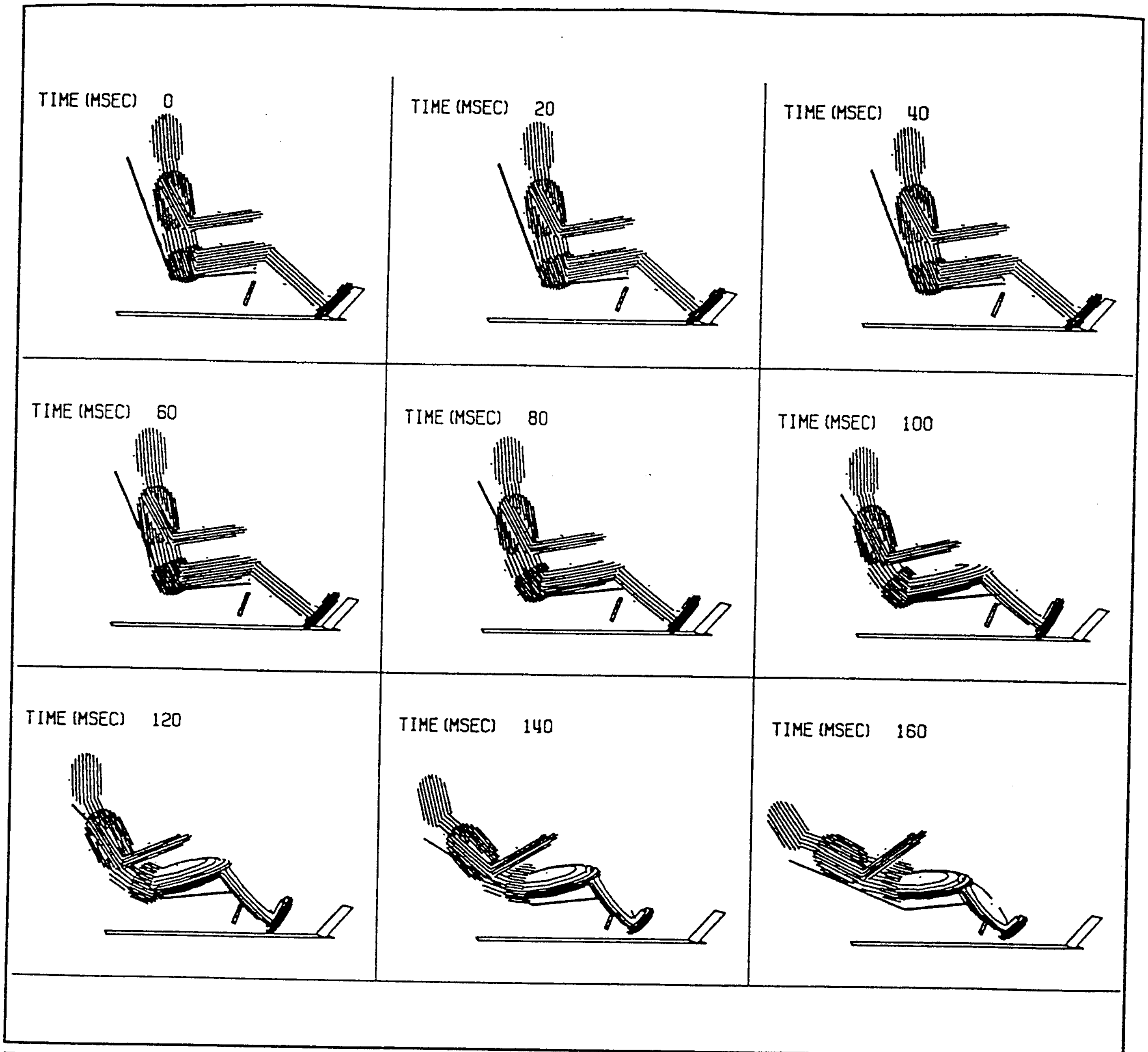

Figure 10 - Example of seat back model using the ATB program.

is defined on the C.2 cards as described earlier, and appropriate contact panels are attached to the second reference segment. It is extremely difficult to model any interior intrusion with detailed contact surfaces. The ATB model limits the detail achievable because of limits on number of segments, contact panels, etc.

However, the ATB model does have the capability to model this scenario with enough detail to provide insight into occupant-interior interaction which will aid any reconstructionist in understanding the collision.

USER CONVENIENCE PACKAGE

The most difficult task in running the ATB model is assembling the data file. The model requires force-deflection data for every contact that may occur, joint flexural spring and damping characteristics for every joint, and detailed geometry of the model environment. Assuming that this data is available or may be obtained through testing, the task of generating an input file for the ATB program is still very difficult. A series of programs were written in the early 1980's to aid in assembling the data file. The programs were called the "Cal-3D User Convenience Package", or UCP[6]. These programs have subsequently been ported down to IBM-PC format.

The UCP consists of several programs that aid in developing and maintaining a database of vehicle interiors, occupant models, ATB force deflection curves, etc. Using the UCP then allows for easier and quicker assembly of an input data file for the ATB program. Each database consists of the actual data fields, structured in the exact format required by ATB. As the user selects the appropriate data to include, that section is read from the

database file and written to the ATB input file.

In addition, the UCP programs keep track of the function numbers and will assign them as required in the contact section of the input file without the user being burdened with this task. The UCP programs are then used to assemble the ATB input file by prompting the user for certain information regarding expected contacts, etc. Figure 11 shows a partial listing of the program session.

The UCP also contains a program that attempts to position the occupant in initial equilibrium. This portion of the package is extremely useful in establishing the initial position of an occupant in the model, but unfortunately, the routine is not always successful. This portion of the package still needs additional work to become completely dependable in positioning the occupant.

DISCUSSION

The ATB model is a valuable research tool for use in understanding occupant kinematics in motor vehicle collisions. The model can be difficult to use due to the generic nature and wide variety of options available. There are a set of general options that can be used to model occupants as part of a collision reconstruction analysis. The ATB model can be successfully used with collision simulation programs such as EDSMAC, SMAC, HVOSM, etc. In this manner, the ATB model is modelling, as closely as possible, the collision pulse generated by the collision simulation programs.

The GEBOD program is a utility program which generates body description data that can be used in the ATB model. The GEBODIII version of the program generates invalid data for small females and should be used with caution. An updated version of the program should be available in early 1995.

The UCP aids in setting up an ATB data file and is also useful in maintaining databases of interior characteristic parameters. The routines in the UCP used to establish occupant equilibrium are useful, but require additional research.

The utility programs discussed in this paper are extremely helpful in setting up an ATB data set, but like all computer programs, the data produced must be analyzed by a qualified user to assure it is reasonable and that it makes sense.

PROGRAM AVAILABILITY

The ATB program and the GEBOD program are available for a distribution fee from Armstrong Laboratory at Wright-Patterson Air Force Base.

DISCLAIMER

The cases presented in this paper are hypothetical. The data has been used for example purposes only and should not be used in any real-world analysis.

REFERENCES

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3. EDSMAC Users Manual, Engineering Dynamics Corporation, Beaverton OR, 1994.

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5. Segal, D.J., "Highway-Vehicle-Object Simulation Model - 1976 User's Manual", NTIS PB 267 401.

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```
FUNCTION SELECTION
PLANE NO.   1  SEAT CUSHION

FORCE-DEFLECTION FUNCTION
ENTER FUNCTION NUMBER
(ENTER 0 FOR NO CONTACTS, 999 TO SEE LIST) : 999

FUNC. NO.    FUNC. NAME

   1      SEAT BOTTOM FDF
   2      SEAT BACK FDF
   3      STIFF SURFACES FDF
   4      DASH - FEMUR FDF
   5      FRONT DASH-FEMUR FDF
   6      DASH - TORSO FDF
   7      HEAD - WINDSHLD FDF
   8      COLUMN - BODY FDF
   9      STEERING COL E/A FDF
  10      SEGMENT-SEGMENT FDF
  11      HARNESS (CABLE) FDF
  12      HARNESS (LAP) FDF
  13      HARNESS (SHLDR) FDF
  14      HARNESS FDF

FORCE-DEFLECTION FUNCTION
ENTER FUNCTION NUMBER
(ENTER 0 FOR NO CONTACTS, 999 TO SEE LIST) : 1

FUNCTION SELECTION
PLANE NO.   1  SEAT CUSHION
INERTIAL SPIKE FUNCTION
ENTER FUNCTION NUMBER
ENTER 0 FOR NO INERTIAL SPIKE, 999 TO SEE LIST) : 0

FUNCTION SELECTION
PLANE NO.   1  SEAT CUSHION
ENERGY DISSIPATION (R) FUNCTION
ENTER FUNCTION NUMBER
(ENTER 999 TO SEE LIST) : 999

FUNC. NO.    FUNC. NAME

   1      SEAT BOTTOM 1
   2      SEAT BACK 1
   3      STIFF SURFACES
   4      DASH - FEMUR 1
   5      DASH - TORSO 1
   6      STEERING COLMN
   7      SEG. - SEG.

ENERGY DISSIPATION (R) FUNCTION
ENTER FUNCTION NUMBER
(ENTER 999 TO SEE LIST) : 1

FUNCTION SELECTION
PLANE NO.   1  SEAT CUSHION
PERMANENT SET (G) FUNCTION
ENTER FUNCTION NUMBER
(ENTER 999 TO SEE LIST) : 999

FUNC. NO.    FUNC. NAME

   1      SEAT 1
   2      STIFF SURFACES
   3      DASH - FEMUR
   4      DASH - TORSO
   5      STEERING COLMN

PERMANENT SET (G) FUNCTION
ENTER FUNCTION NUMBER
(ENTER 999 TO SEE LIST) : 1
```

```
FUNCTION SELECTION
PLANE NO.   1  SEAT CUSHION
FRICTION COEFFICIENT FUNCTION
ENTER FUNCTION NUMBER
(ENTER 999 TO SEE LIST) : 999

FUNC. NO.    FUNC. NAME

   1      FRICTION MU=1.0
   2      FRICTION MU = 0.75
   3      FRICTION MU=0.5
   4      HARNESS 1
   5      HARNESS 2
   6      CONSTANT, F=0.0

FRICTION COEFFICIENT FUNCTION
ENTER FUNCTION NUMBER
(ENTER 999 TO SEE LIST) : 2
.........................................
.........................................
   FORCE DEFLECTION FUNCTIONS
  FUNCTION SELECTION BY PLANE
    PLANE     FUNCTION NO.
 1  SEAT CUSHION            1
 2  SEAT BACK               2
 3  FLOOR BOARD             3
 4  TOE BOARD               3
 5  WINDSHIELD              7
.........................................
.........................................
DO YOU WANT TO MAKE ANY CHANGES (YES OR NO)   N
.........................................
.........................................
      FRICTION FUNCTIONS
  FUNCTION SELECTION BY PLANE
    PLANE     FUNCTION NO.
 1  SEAT CUSHION            2
 2  SEAT BACK               2
 3  FLOOR BOARD             1
 4  TOE BOARD               1
 5  WINDSHIELD              3
.........................................
.........................................
DO YOU WANT TO MAKE ANY CHANGES (YES OR NO)   N

PLANE CONTACT SELECTION
ENTER NO. OF SEGMENTS CONTACTING PLANE  1
SEAT CUSHION        : 3
ENTER SEGMENT NOS. FOR CONTACT WITH THIS PLANE
CONTACT NO.  1
INPUT SEGMENT NO. :  1
CONTACT NO.  2
INPUT SEGMENT NO. :  6
CONTACT NO.  3
INPUT SEGMENT NO. :  9

PLANE CONTACT SELECTION
ENTER NO. OF SEGMENTS CONTACTING PLANE  2
SEAT BACK           : 3
ENTER SEGMENT NOS. FOR CONTACT WITH THIS PLANE
CONTACT NO.  1
INPUT SEGMENT NO. :  1
CONTACT NO.  2
INPUT SEGMENT NO. :  2
CONTACT NO.  3
INPUT SEGMENT NO. :  3
.........................................
.........................................

   PLANE                   SEGMENT CONTACTS
NO.     TITLE           NO.          SEGMENTS

 1 SEAT CUSHION          3:  1-LT  ,  6-RUL ,  9-LUL ,
 2 SEAT BACK             3:  1-LT  ,  2-CT  ,  3-UT  ,
 3 FLOOR BOARD           2:  8-RF  , 11-LF  ,
 4 TOE BOARD             2:  8-RF  , 11-LF  ,
 5 WINDSHIELD            1:  5-H   ,
.........................................
.........................................
DO YOU WISH TO MODIFY ANY CONTACTS (YES OR NO) ? N
```

Figure 11 - Partial listing of UCP session.

Development of a Simulation Database for the Advanced Dynamic Anthropomorphic Manikin (ADAM)

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Gregory Thompson
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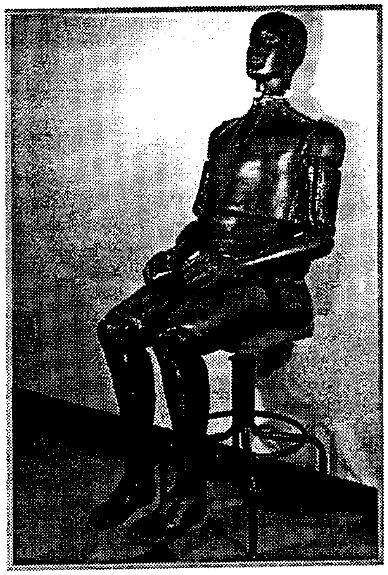
Introduction

- **Advanced Dynamic Anthropomorphic Manikin (ADAM) is a human surrogate used for high-speed ejection testing**
- **Full-scale testing is expensive and time-consuming**
- **Want to supplement testing with computer simulations**
  - » Provides additional data not available from tests
  - » Use as design tool <u>before</u> prototype testing



- ADAM designed to reproduce human characteristics
- ADAM's design constraints:
  - biofidelity
  - joint motion measurement
  - durability
- Constraints ⇒ compromises ⇒ differences between humans and ADAM

Overview

- Approach
- Data Requirements
- Testing & Modeling Methods
- Verification
- Recommendations

Approach

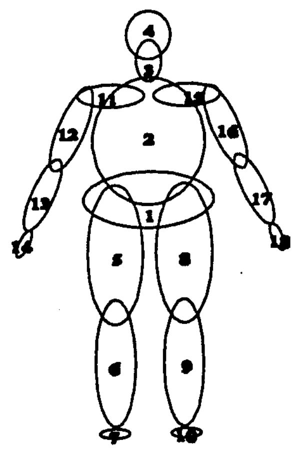
- Measure ADAM's physical characteristics
- Analyze and format for input into simulation program
- Verify that data was input correctly
- Validate data set

Required Data

- Segment and joint configuration
- Segment inertial properties
- Ellipsoid dimensions and offsets
- Joint locations
- Joint torque characteristics

ADAM Model Configuration

- 18 Segments
- 17 Joints
  - » 15 "Euler" joints
  - » 2 ball & socket joints



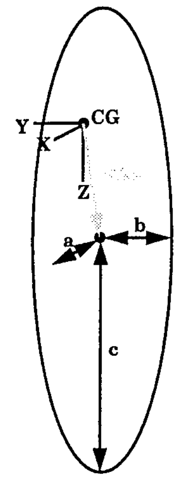
Seg No.	Seg Name
1	LT
2	UT
3	N
4	H
5	RUL
6	RLL
7	RF
8	LUL
9	LLL
10	LF
11	RCL
12	RUA
13	RLA
14	RH
15	LCL
16	LUA
17	LLA
18	LH

Inertial Properties

- Required for each segment:
  - » Mass
  - » Center of gravity location
  - » Principal moments of inertia
  - » Orientation of principal axes
- STandard Automated Mass Properties (STAMP) Testing Procedures

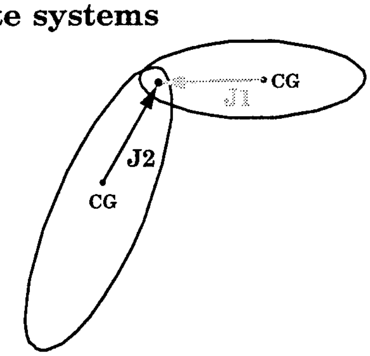
Segment Coordinate System and Ellipsoid Dimensions

- Z semiaxis derived from joint locations
- X and Y semiaxes derived from circumference and diameter measurements
- Segment coordinate system origin located at CG
- All segment dimensions given with respect to segment coordinate system



Joint Locations

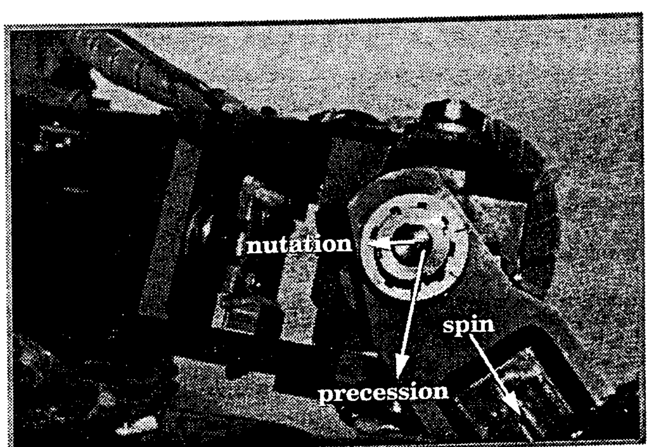
- Measured during STAMP procedure with three-dimensional digitizer
- Referenced to both adjoining segments' coordinate systems



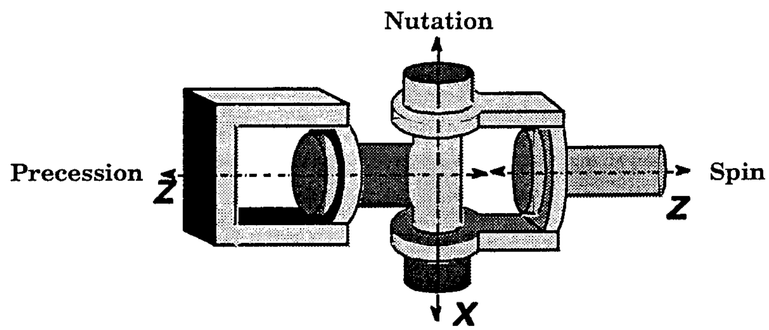
Joint Characteristics

- ADAM neck taken from standard Hybrid III data set
  - » Two ball-and-socket joints
  - » Each has three angular degrees of freedom
- All other joints use Euler joint model
  - » Rotations and torques applied about precession, nutation, and spin axes
  - » Different torque-angle characteristic for each rotation
  - » Individual joint axis rotations may be locked

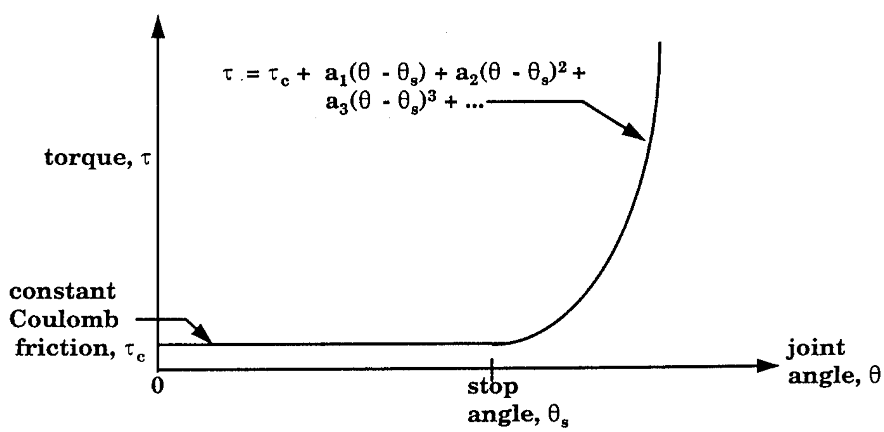
Shoulder Joint



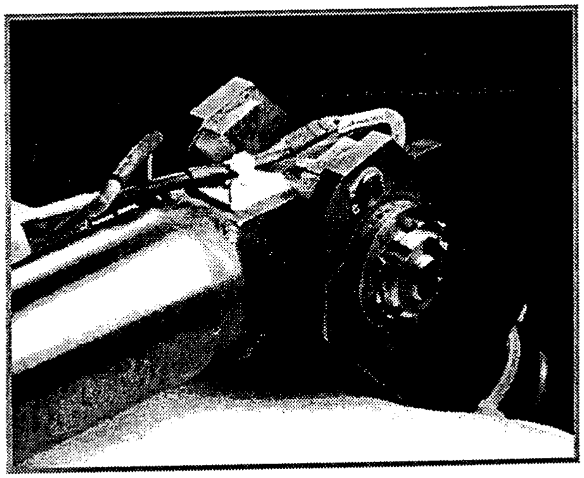
Euler Joint



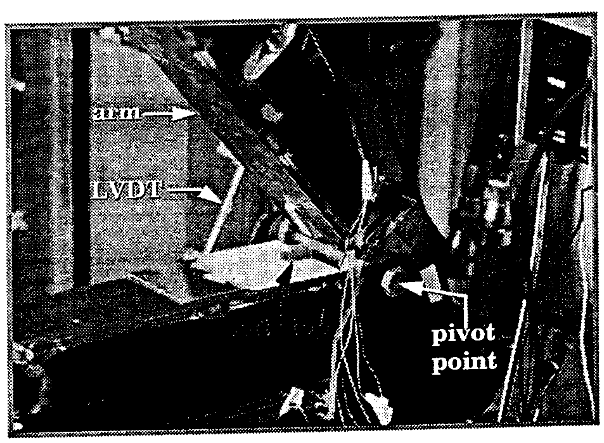
Joint Resistive Torque



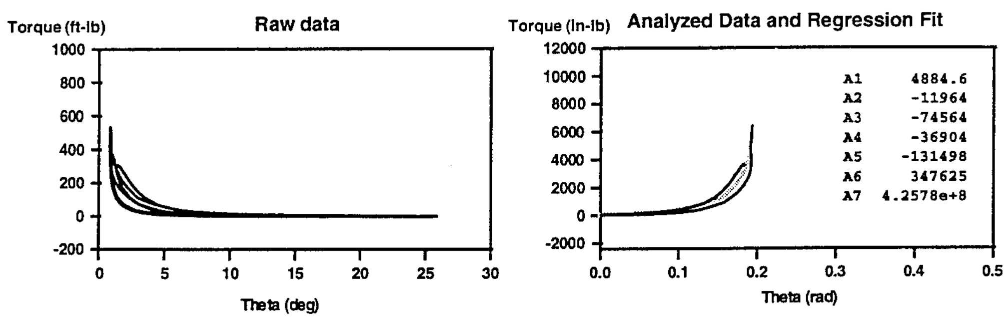
Soft Stops



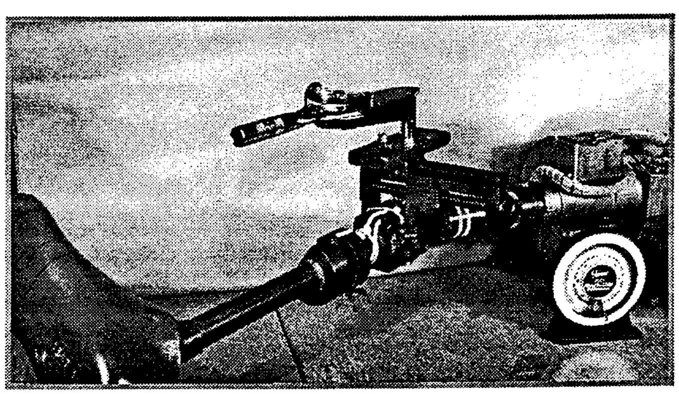
Soft Stop Test Anvil



Elbow Flexion/Extension
Soft Stop Data



Coulomb Test Setup



Verification

- Static & Dynamic Simulations
  - » Ensure proper data input
  - » Ensure proper data handling by ATB program

Summary

- Large ADAM measured
- ATB data set developed
- Initial verification conducted

Recommendations

- Validate against horizontal sled and ejection test results
- Develop small ADAM data set
- Use to supplement future AL tests

Opportunities for Casualty Reduction in Rollover Crashes

K. H. Digges, A. C. Malliaris, and H. J. DeBlois
DeBlois Associates
United States
Paper No. 94-S5-O-11
1994 ESV Conference

EXCERPT

CHARACTERIZATION OF THE ROLLOVER ENVIRONMENT

Earlier studies [Terhune 1988, Malliaris 1991] suggest that the most common type of rollover involves a vehicle slipping sideways and incurring tripping acceleration, which induces the rollover. Terhune found that 70% of the cars, and 91% of the vans and pickups had tripping induced rollovers. Malliaris reported that precrash events which can induce lateral slide are predictors of rollover incidence, and that vehicle angular motion about the roll axis is recorded in more than 95% of the rollover cases.

Analysis of NASS rollovers shows that two thirds of all vehicles in rollovers undergo less than one complete revolution (three or less quarter turns). This group of rollovers accounts for 46.6% of the harm to occupants. The remaining 54.4% of the harm occurs in vehicles which undergo one or more revolutions. The mean precrash speed for rollovers is 50 mph, compared to 28 mph for all other crashes. For rollovers in which a fatality is involved, the mean speed is 63.4 mph, compared with 45.3 mph for all other fatal crashes [Malliaris 1991].

Estimates of the roll rate were made by analyzing the trajectory of vehicles from 140 cases reported in NASS. The cases were selected from the 900 rollovers in 1989-90 NASS on the basis of extent of damage. All cases in the file with severe damage (Collision Damage Classification of 4 or more) were included in the study. The mean precrash speed for these cases was 56 mph, and the mean roll rate was between 1 and 2 rev/sec. In 89% of the cases, the rollover was the most harmful event. The tripping force was the most harmful event in most of the remaining cases. The roll direction was 43% clockwise, 46% counterclockwise, and 11% unknown.

SIMULATION OF OCCUPANT KINEMATICS IN ROLLOVERS

Testing of countermeasures in rollover has been extremely limited to date. Laboratory testing is limited by the lack of facilities which can subject a dummy to the rollover crash environment. There is no rollover equivalent to the crash test sled which is used for developing safety systems for planar impact environments. A great deal of useful information has been gained from rollover testing of complete vehicles. During the past ten years, rollover tests conducted by the Department of Transportation have been of two types.

The first type of rollover is induced by a median barrier designed to redirect vehicles back into the roadway. However, as the angle and speed of engagement with the barrier are increased, a rollover may result. The roll rate observed when a midsize vehicle traveling at 60 mph engages the median barrier is about 1 rev/sec.

The second type of test is a staged rollover induced by

ejecting the vehicle from a moving a test cart. The test cart contains platform which is hinged perpendicular to the direction of travel. The vehicle is placed on the platform at an angle (usually 45 degrees or 90 degrees) relative to the direction of travel. The cart and vehicle are towed to speed (30 mph or less) and the vehicle is ejected by rapid rotation of the platform and sudden deceleration of the cart to obtain the rollover. The roll rate is generally less than 1 rev/sec.

Computer modeling of rollover crashes permits precise and repeatable control of the rollover environment, and permits the study of a wide range of rollover conditions at low cost. Computer simulations of vehicles and occupants in rollover crashes have been developed under sponsorship of NHTSA and published in the literature [Obergefell 1986, Smith 1993]. These papers describe models which have been validated for the two kinds of tests described above. However, in both of these rollover test types, the tripping acceleration which induced the rollover is relatively low. The simulations described in this paper introduce tripping acceleration into the validated models developed for NHTSA.

Based on an analysis of the predominate rollover environments, scenarios for rollover simulations have been developed. The initial goal of the simulation is to explore occupant motion during the initial phase of the rollover. This phase begins at the pre-roll conditions including skidding, tripping and launching accelerations. It includes the subsequent linear and angular motion of the vehicle, ending just before the first impact with the ground. For the simulations reported in this paper, the vehicle is initially sliding sideways. It trips, and then rolls about the vehicle roll axis. The magnitude of the tripping acceleration is specified by delta V. It is applied in conjunction with angular acceleration over a period of 120 ms.

DISCUSSION OF EJECTION CONTROL

Increased restraint use is a readily available opportunity for reducing ejections. In addition, earlier analysis suggests that occupant containment within the vehicle provides major benefit in rollovers, even for unrestrained occupants [Malliaris 87]. Based on the ejection paths shown in Table III, countermeasures to reduce ejections through closed side windows offer large opportunities for intervention. Other opportunities include the sun roof, and the windshield.

The simulation selected to examine the side window ejection opportunity was the tripped rollover described earlier. Variation of two variables were investigated: the severity of the tripping event (specified by delta V), and the roll rate. The occupant was a 50% male Hybrid III dummy in the driver position. The roll motion was counterclockwise and the simulation encompasses roll motion of 270 degrees. Post rollover ground contact was not included. Representative results are shown in Table V.

In these simulations the side windows were initially open. Ejections were not produced during rollovers at 0.5 and 1.0 rev/sec when the tripping delta was only 1 mph. However, as the tripping severity increased to 5 mph, ejection of the head resulted at 0.5 rev/sec, and complete ejection resulted at 1.0 rev/sec. At higher tripping severities, complete ejection was produced at both roll rates.

A repeat of the simulations with ejection resistant glazing in the side window were made. The glazing characteristics similar to those exhibited in laminated windshields were assumed. The glazing prevented ejection in all cases. The maximum forces exerted on the glazing by the dummy were well below the strength of currently used windshield interlayers.

NHTSA has reported successful testing of ejection resistant side windows and windshields [Clark 89]. This research evaluated the penetration resistance of the glazing by laboratory tests and the rollover performance by crash testing in actual vehicles. The stated design goals for ejection resistant glazings included resisting a 40 lb ball impact at 20 mph, and maintaining integrity during a rollover. Rollover tests of eight vehicles with experimental ejection resistant side windows have been reported. The integrity of the side glazing was maintained in all tests. In the eight tests reported, the number of quarter turns ranged from 1 to 8, and the vehicle deformation at the right A-pillar ranged from .4 to 9.1 inches.

Additional research and analysis are now needed to assess the range of crashes which could be accommodated by advanced glazing technology and to estimate the benefits which might be achieved.

TABLE III
EJECTION PATHS IN ROLLOVER CRASHES
ALL LIGHT VEHICLE OCCUPANTS

EJECTION PATH	ALL EJECTEES	RESTRAINED EJECTEES
CLOSED GLAZING	43.7	43.8
OPEN GLAZING	14.7	31.4
WINDSHIELD	6.8	9.0
DOOR/GATE	11.9	0.3
SUNROOF	11.9	12.0
OTHER/UNK.	10.9	3.5

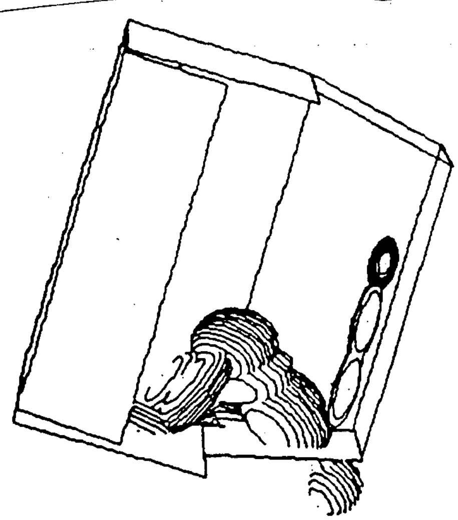


Figure 2. Rollover Model, Head Ejection 0.5 Rev/Sec; 5 MPH Tripping Delta-V

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The Use of ATB/DYNAMAN in Injury Biomechanics

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INTRODUCTION

The Articulated Total Body (ATB) program was originally designed by CALSPAN with the intent of improving occupant safety and developing modern safety standards for the automotive industry. In recent years, the versatile software has been applied to the analyses of injury biomechanics resulting from various accidents.

To date, ATB has been used to model the kinematics and dynamics of occupants in a much wider range of accident scenarios, including estimating joint forces and moments and segment accelerations and contact forces. If the estimated motions and/or loads of an ATB analysis are compared to critical injury-producing values which have been estimated or experimentally obtained from the literature, then one can estimate the likelihood of various injuries in a particular accident. In some cases, detailed vehicle motions are not known *a priori* and must be estimated along with the occupant kinematics so that potential injuries may be analyzed. Three examples of ATB simulations are discussed which demonstrate how ATB can be used to perform an injury analysis for different vehicular accidents.

FRONTAL COLLISION EXAMPLE

A sports car underwent a 35 mph longitudinal Delta-V in a head-on collision with the side of a swerving van. The unbelted front seat passenger of the automobile sustained a neck fracture resulting in quadriplegia, a forehead laceration, and loss of consciousness. The ATB program was used to investigate the effectiveness of a 3-point seat belt in this scenario.

An ATB model of the car interior was created based on measurements of an exemplar vehicle. Geometric and inertial properties of the occupant were created from height, weight, and gender data automated in the GEBOD program. Vehicle stiffness data were taken from the data set supplied along with the ATB program [1-3].

The simulation of the unbelted occupant produced joint forces and moments consistent with the resulting injuries, while a simulation which included a 3-point seat belt showed that the occupant would have experienced no head or knee contact with the vehicle interior and would not have been seriously injured.

FORKLIFT ACCIDENT EXAMPLE

In another application, ATB was used to analyze injuries associated with a forklift accident. In this case, ATB was used to not only estimate the dynamics of the occupant of the forklift but also of the forklift itself. In most automobile accidents, the mass of the vehicle is at least an order of magnitude greater than the mass of the occupant, and hence one can assume that the vehicle dynamics are not significantly affected by the occupant kinematics. In this case, however, the seat was attached to the vehicle through a hinge, and hence the seat's motion needed to be considered. Therefore, a coupling dynamic analysis including the forklift and occupant was performed.

The geometry of the forklift chassis, tires, seat, and the rollover protection structure (ROPS) in the ATB model were obtained by measurements of an exemplar forklift. The center of gravity and inertia data were computed using the geometric data and standard formulae. Seat properties were obtained by performing compression tests.

Since the head injury parameters were the subject of concern, care was taken to determine this parameter rigorously. A beamlike structural stiffness was added to the head stiffness obtained from the biomechanics literature [4-6].

A dynamically-coupled ATB analysis of the

forklift was performed to analyze forces between the subject's head and a ROPS (rollover protective system). Results showed that the occupant's head impacted the ROPS structure before the ROPS structure impacted the ground, and hence the injury was not caused by forces to the head from a deforming ROPS.

BUGGY ROLLOVER EXAMPLE

A final example involves simulating a dune buggy in a rollover accident. As in the second example, this case required simulating both the occupant and vehicle kinematics using ATB.

The ATB model was created based on measurements of an exemplar vehicle, and inertial properties were determined from experimental tests. Witness statements were used to estimate the starting point of the roll and the final rest position. The simulation of the roller provided understanding of the inertial loads imparted to the vehicle occupants and the seat belt restraint system.

SUMMARY

By using ATB to calculate joint moments or segment contact forces and combining these estimates with critical values from the literature, an injury analysis can be performed. Three examples have been discussed which demonstrate many of the important issues involved in performing an injury analysis via computer simulation using the ATB program.

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The Use of ATB/DYNAMAN in Injury Biomechanics

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Introduction

- Original intent of developing ATB
  - Improve occupant safety
  - Develop safety standard
    + occupant kinematics
    + occupant dynamics
    + human injury tolarence
  - Rigid-body dynamics program
  - Biomechanics literature
  - General purpose rigid-body dynamics programs are very tedious and time consuming for occupant modeling.

Introduction

- A customized version was developed by Calspan: Crash Victim Simulator (CVS), later modified by Air Force (ATB). Calculations of injury tolerance were included in CVS/ATB.

- Although the original intent of the program was performing crash victim simulation, this program can still be used as a general rigid-body dynamics (open loop) program with impact capabilities.

Introduction

- Versatility of the program will be demonstrated through following three examples:
  + Effectiveness of seatbelts in motor vehicle accident (frontal)
  + Study of head injury mechanism in a forklift rollover accident
  + Dynamics of a dunebuggy rollover in sand dunes

History of ATB use at FaAA

- Started using ATB in 1984
- Area of applications
  - Motor vehicle accident analysis
  - Fall dynamics
  - Human / machine interaction analysis
  - Occupant safety in new vehicle design

Examples

- Effectiveness of seatbelt use
  - Actual accident happened during filming of a chase scene of "Cannonball Run" movie on a road in Nevada desert.
  - Accident reconstruction
    + Sports car colliding head-on with the side of a swerving van. Delta-V = 35 mph
  - Injury analysis
    + Neck fracture resulting in quadriplegia
    + Forehead laceration and loss of consciousness

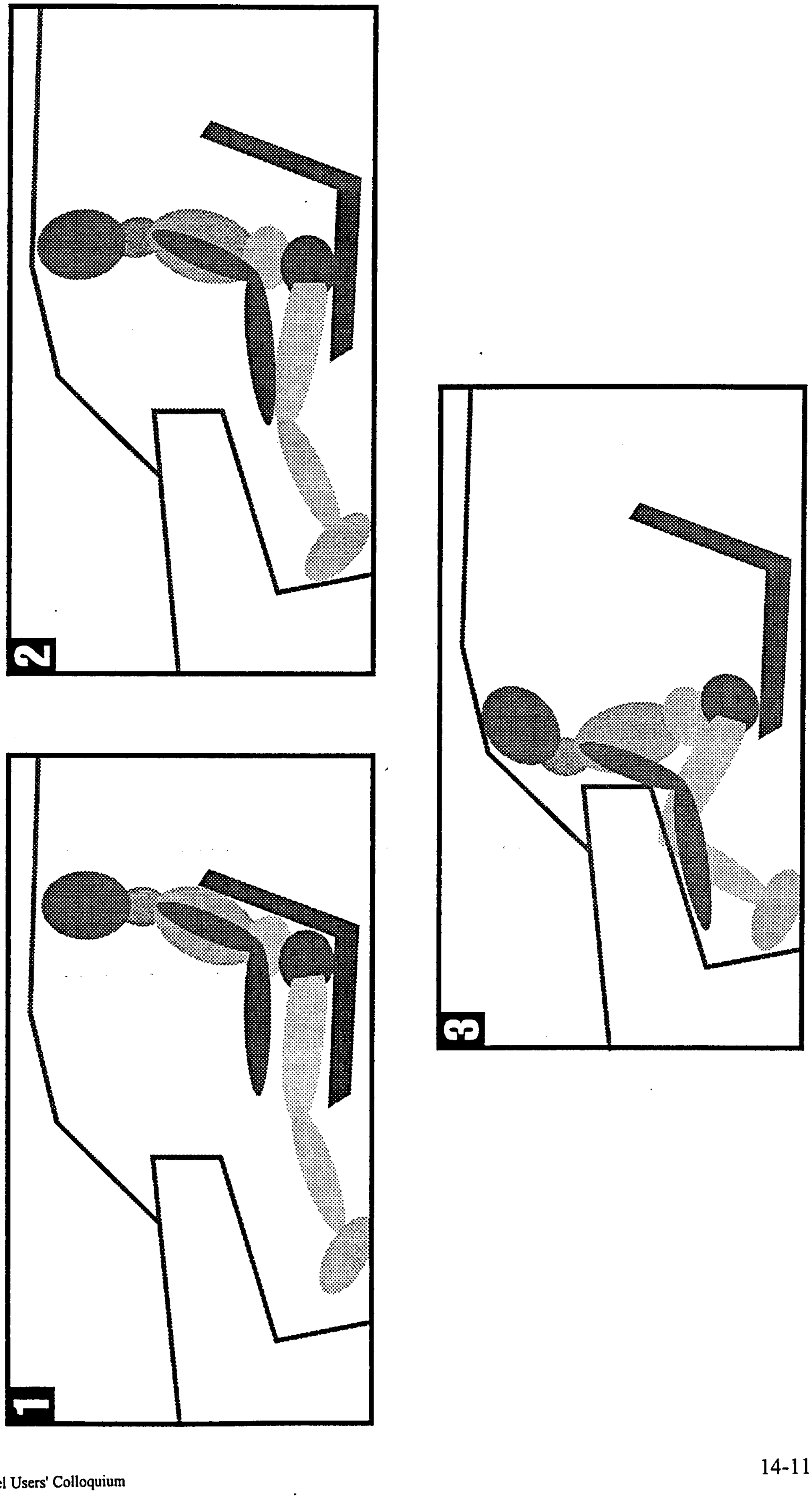
Effectiveness of seatbelt usage

- ATB analysis
  - Vehicle data : Model of vehicle interior was based on measurements of an exemplar vehicle.
  - Occupant data : Geometric and inertial properties of the occupant were generated from height, weight, and gender data using the GEBOD program.
  - Vehicle Interior stiffness data : Most of the data were taken from data set supplied along with the ATB program.

Effectiveness of seatbelt use

- Vehicle motion : The 35-mph longitudinal delta-v determined by the accident reconstruction was represented by a half-sine pulse of 24.4 g.
- Validation of model : The input parameters of the model were validated by studying the occupant motion and loads indicated by the ATB output.
- Unbelted occupant model : The model for the unbelted occupant is shown in the next slide.

Effectiveness of Seatbelt Use - Unbelted Occupant



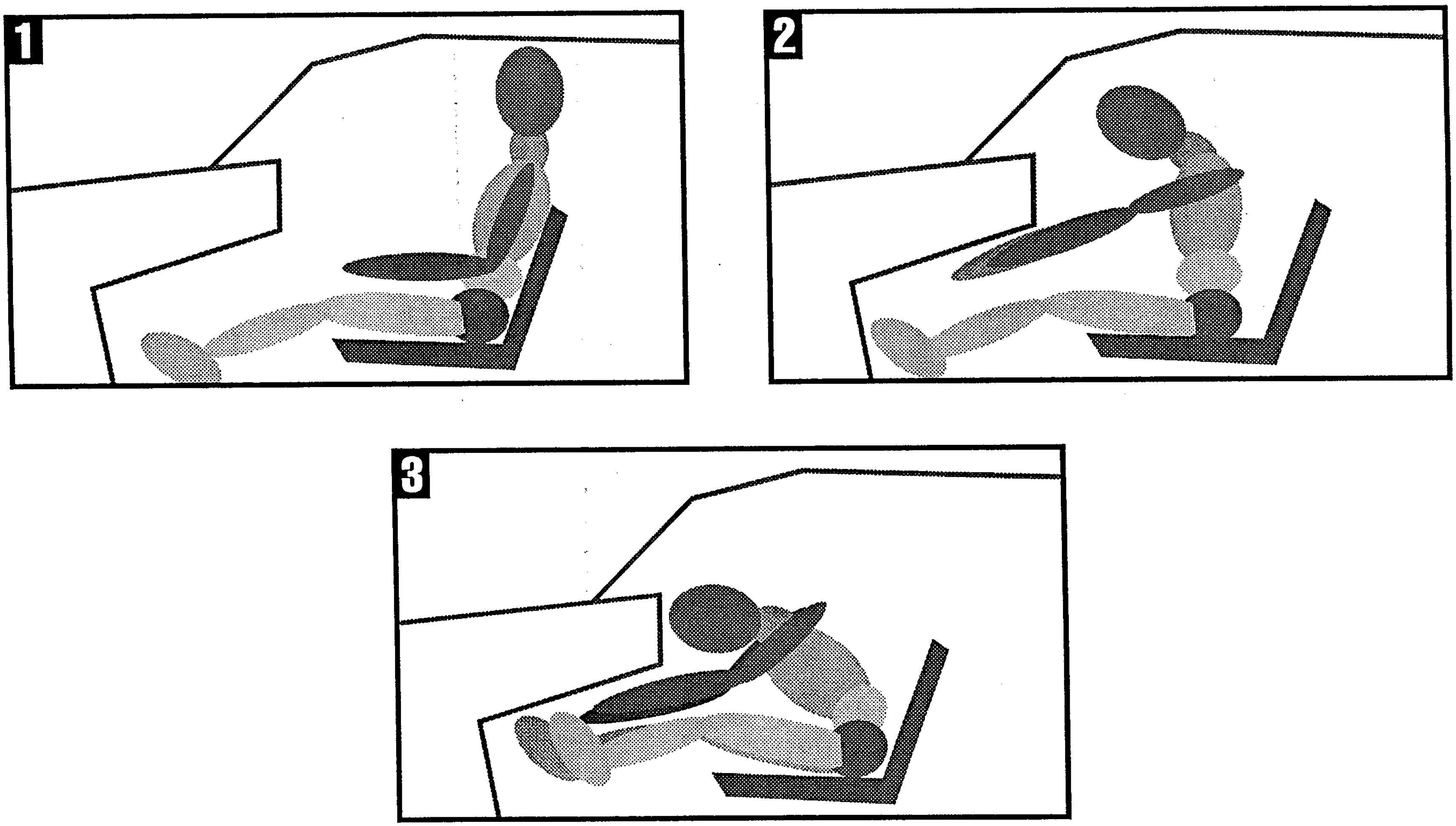
Effectiveness of seatbelt use

- Unbelted occupant model
  - The motion shows her head would strike the windshield, which correlates with the laceration observed on her forehead.
  - HIC : 1552, Neck moment : 232 ft lbs.
  - HIC of 1552 is consistent with a 50 percent probability of a concussion-type head injury. This correlates very well with the passenger's loss of consciousness and lack of permanent head injury.

Effectiveness of seatbelt use

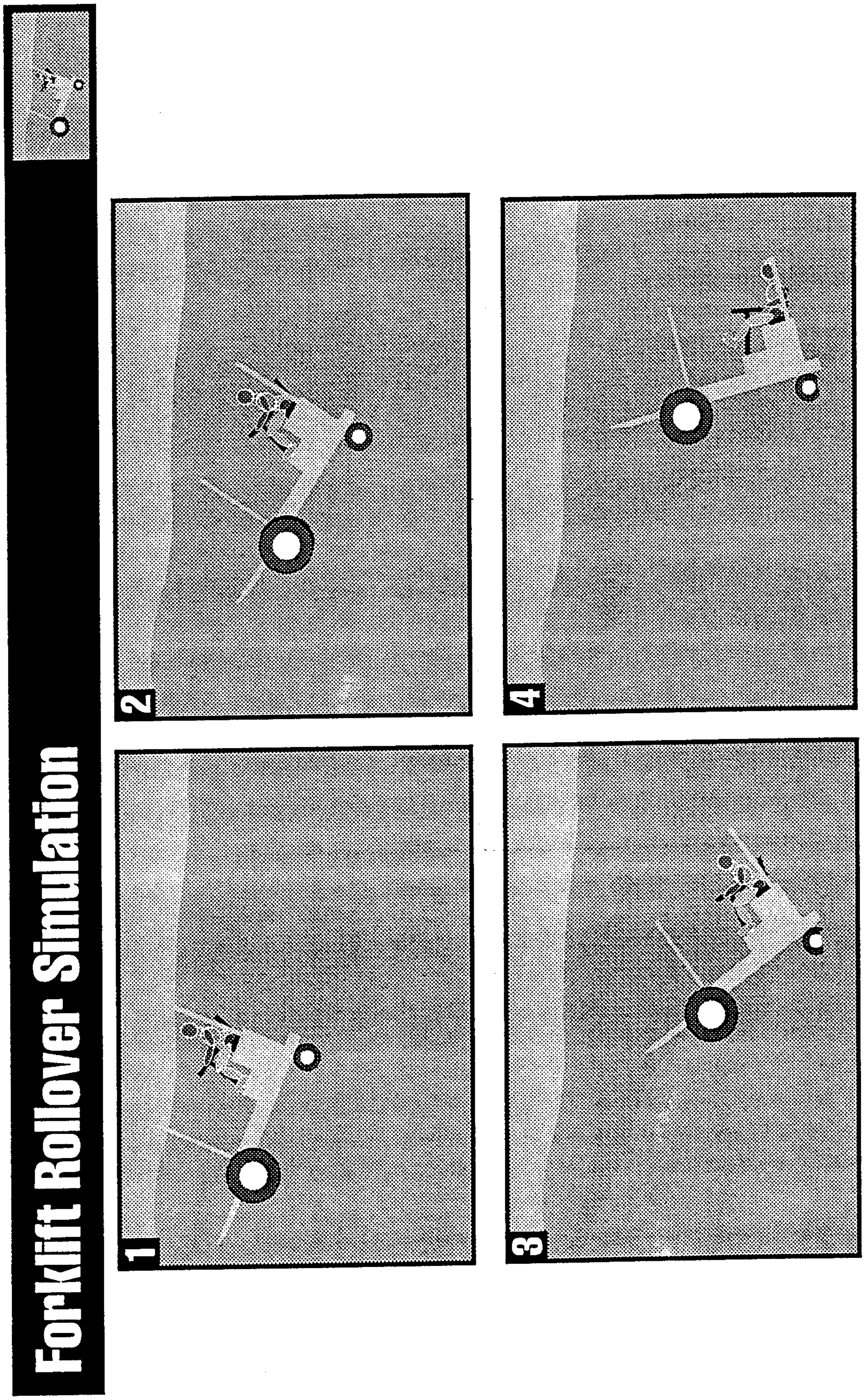
- Unbelted occupant model
  - The neck moment was 5.5 times the tolerance level (extension moment : 42 ft lbs.) and consistent with the occupant's neck injury.
- Belted occupant model
  - The occupant motion is shown in the next slide.

Effectiveness of Seatbelt Use - Belted Occupant



Effectiveness of seatbelt use

- Belted occupant
  - No head or knee contact with the vehicle interior.
  - The computed loads and accelerations would not have produced serious injury.


Forklift Rollover Simulation
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2
3
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Forklift rollover simulation

- Accident description
  - The forklift slid down sloped ground, over a retaining wall, and onto the road about 6 ft below, where it then fell backward.
  - Operator was unbelted.
  - Two injury mechanisms were studied : (1) Head was injured by the ROPS after it bent upon hitting the ground.
    (2) Head was injured by the ROPS before ROPS struck the ground.

Forklift rollover simulation

- ATB analysis
  - Due to the complexiety of the forklift construction, a rigorous model is used to capture occupant's motion.
  - Dynamically uncoupled simulation : Most simulations are performed assuming that the motion of the vehicle is unaffected by the motion of the occupant.

Forklift rollover simulation

- Dynamically coupled simulation : In some situations, a flexible component of the vehicle may have effect on the overall motion of the occupant and vehicle.
- In the present example, the seat is connected to the forklift by a pair of hinges, and as such the seat can rotate with respect to the forklift during the fall motion. Therefore, a combined (dynamically coupled) model of the forklift chassis, seat, and the occupant is required.

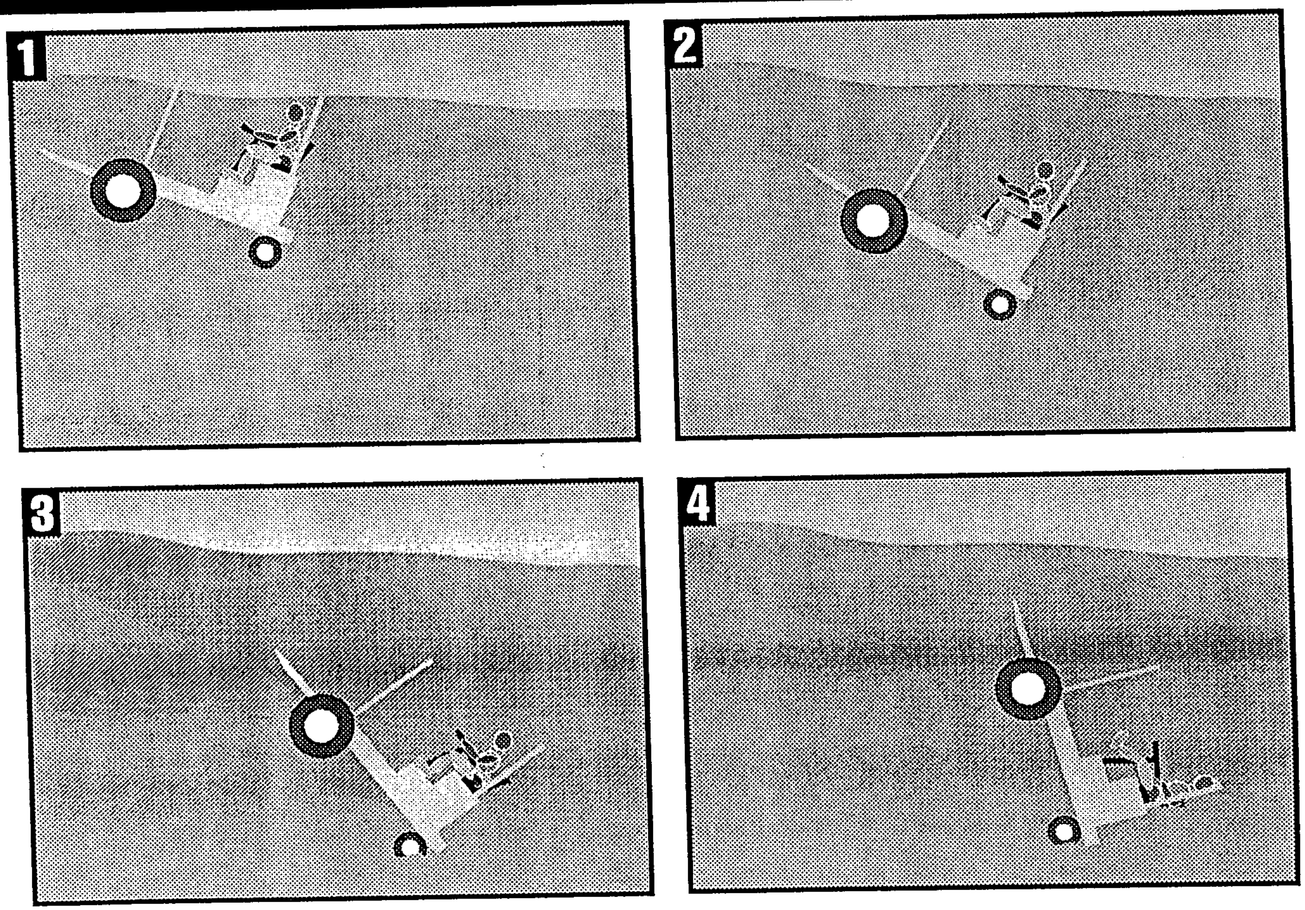
Forklift rollover simulation

- Forklift geometry : Geometry of the forklift chassis, tires, seat, and ROPS were obtained by measuring an exemplar forklift.
- Inertial data: The CG and inertial data for the forklift were computed using the geometrical measurements and simple formulas. Seat properties were obtained by performing simple tests.

Forklift rollover simulation

- Head / ROPS stiffness data : Since the head injury parameters were the subject of concern, it was important to determine this parameter rigorously. A beamlike structural stiffness was added to the head stiffness obtained from the biomechanics literature.

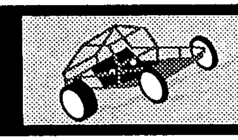
Forklift Rollover Simulation

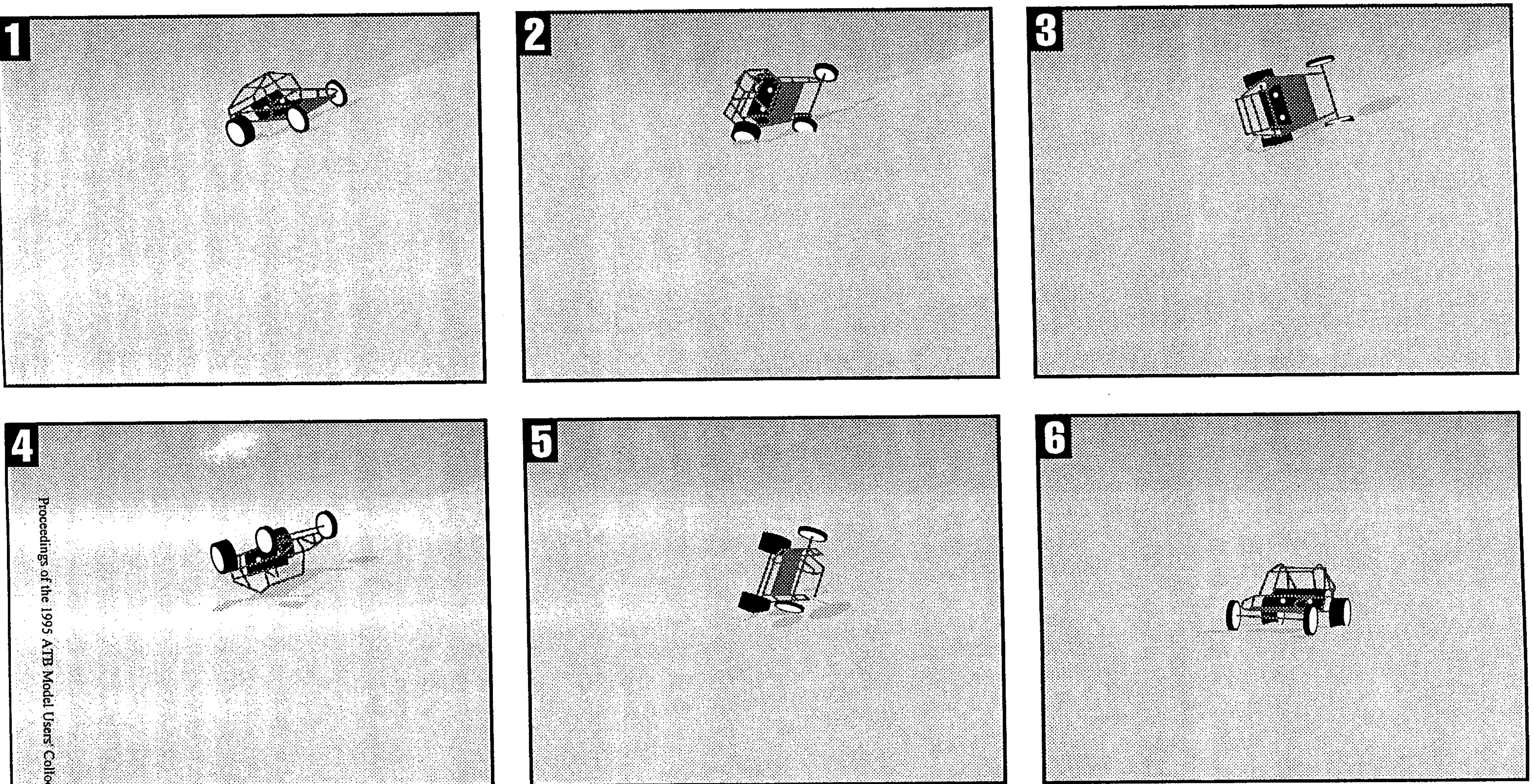


Forklift rollover simulation

- The forklift was allowed to roll down the slope under gravity loading.
- The simulation showed that the unbelted occupant's head hit the ROPS before the ROPS hit the ground.

Dune Buggy Rollover Simulation





Dunebuggy rollover simulation

- Accident description and work scope
  - Dunebuggy with two occupants rolls 360 degrees sideways along the sloped surface of a sand dune.
  - Study the effectiveness of the seatbelt locking mechanism.
- ATB analysis
  - Complexiety of the modeling : Occupants are interacting with dunebuggy structural components and the ground.

Dunebuggy rollover simulation

- Phase I study : Study dunebuggy dynamics by modeling occupants as point masses.
- Dunebuggy model data : Mass and inertial properties were obtained by direct measurement and simple tests.
- Eyewitness testimonies were used to establish the starting point of roll and final rest position. These records revealed that the dunebuggy made one full roll.

Dunebuggy rollover simulation

- Simulation was performed for about 4400 msec.
- Phase II study : Purpose of the phase II study is to model occupants and seatbelts along with the dunebuggy. However, this phase never started due to financial reasons.

Use of DYNAMAN for Design and Development of Anthropometric Test Devices

T. Shams and Y. Zhao, GESAC, Inc.

1. Introduction

DYNAMAN is being used extensively as a tool to aid in the design of a number of components for an enhanced anthropometric test device which is currently under development. The ATD, which is called the Trauma Assessment Device (TAD), will have a number of enhanced components, with improved anthropometry and biofidelity [1]. These include the thorax, abdomen, neck, head/face, and lower leg assembly. In this presentation, we will provide a number of examples where DYNAMAN has been used to model several components and their responses under impact forces or accelerations. In particular, the modelling of a new abdomen assembly and a new neck will be described.

The DYNAMAN models are being used to provide a fast, practical procedure for selecting the basic characteristics of different hardware parts of a component, such its geometry and stiffness. The models allow one to vary the important design parameters to under the sensitivity of the response to these parameters. In some cases, the modelling is being used as a preliminary procedure for identifying these characteristics before proceeding with more advanced modelling using finite elements. But in our experience, we have found that for materials such as rubbers and foams, which are somewhat difficult to characterize within the context of a finite element model is more easily defined using the lumped parameters used in DYNAMAN, where only the average response is required.

The first step in all the modelling exercises, is to select the modelling elements (e.g. ellipsoids, joints, spring-dampers, airbags, belts), that will best describe a particular portion of a dummy component. The appropriate geometry associated with a modelling element is next determined. The geometry is usually guided by the actual physical features of the part, though in some cases, compromises will need to be made in order to fit a lumped parameter to what is really an extended object. The next objective in the modelling is to select the response parameters which would make the component behave in a way similar to what is suggested by the design goals. These may include the force-deflection characteristics of an impact surface, elastic and viscous properties of a spring damper, etc.

2. Modelling of the Abdomen

The current abdomen is a frangible insert made of styrofoam, which was originally designed to be used with the Hybrid III dummy [2]. It has "human-like" force-deflection characteristics when loaded by belts, but can only measure the maximum

deformation and has to be replaced after each test. A number of researchers have examined the possibility of using a foam-filled bag as the surrogate structure for the abdomen [3,4].

As part of a detailed analysis of the possible alternatives that could be used for the design of a new abdomen, an initial model was developed with DYNAMAN which described a structure which included both the effects of the foam and of the enclosed air. The enclosed air was modeled because one of the possible choices for the foam was to selected an open-cell foam where a significant percentage of the volume of the foam is taken by air. During the compression of a such a structure, resistance will be offered by both the elastic/damping characteristics of the material of the foam, and by the "air spring" effect of the compressed volume of air.

The initial steps in the development of the model consisted of the following:

1. Determination of the approximate geometry of the structure. This included the dimensions available for assembly in height, weight, and breadth. The dimensions were dictated partly by the space available in the lower section of the thorax between the lower ribcage and the pelvis. The main design restrictions were the area of the abdomen that would be exposed in the front. This should be reasonably similar to the exposed area of a human abdomen which may be impacted by steering wheels or belts.
2. Determination of the constraint conditions on the structure. Alternatives included structures which could rotate about the lumbar spine (in the pitch direction) and those where the abdomen was more rigidly attached between the spine and the front of the lower thorax.
3. Determination of the different impact situations that would need to be modeled. At the preliminary stage our main interest was to model the effects of a rigid rod impacting the upper portion of the abdomen (similar to a steering wheel impact) and that of a lap belt impacting the lower abdomen.

The basic components of the model were:

1. A spring-damper system which modelled the foam characteristics within the bag.
2. An airbag which modelled the air spring characteristics of the bag.
3. A small mass segment (with associated ellipsoid) which modelled the inertial and stiffness characteristics of the bag cover which would be in immediate contact with the impacting object.

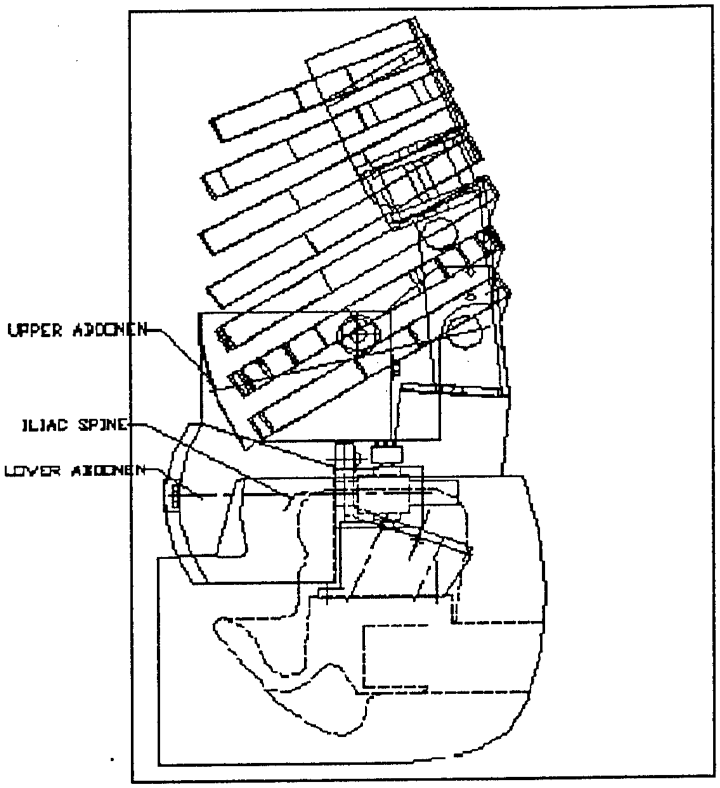


Figure 1. General layout of abdominal segment within the dummy.

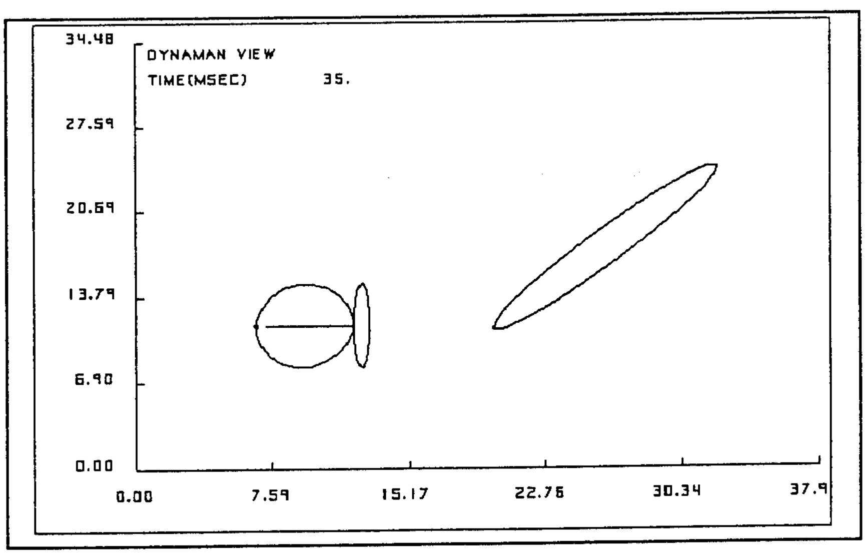


Figure 2. Initial setup of spring-damper plus airbag model of abdomen.

Figure 1 shows the layout of the area of the dummy where the abdominal segment will reside. The principal attachment is with the spinal column and the figure shows that the upper abdominal

area overlaps the lower ribcage and the lower abdominal area which sits on top of the pelvis. Figure 2 shows the basic abdominal model which consists of a spring-damper, and airbag, a mass segment (the front ellipsoid) which represents the cover. The spring-damper attaches the lower torso segment (lower spine) with the abdomen cover segment. An ellipsoidal airbag was defined (though a cylindrical bag could also be defined) and was attached to the lower torso segment. The airbag was inflated in such a way that it was fully inflated (at atmospheric pressure) before any impact could occur (DYNAMAN cannot generate a preinflated bag, but has to use a mass flow rate function to feed gas into the bag.) The initial model analyzed the impact of a steering wheel (represented by an ellipsoid) at an angle of 45° with the bag cover segment.

NOTE: Some care has to be taken in defining the contact region of the bag with the impactor, since the penetration algorithm used can fail, once the center of the penetrating segment passes the center of the bag.

Once the basic model was operational, the whole bag assembly was then inserted within the Hybrid III dummy (replacing the existing lower torso). This model was exercised using both impacts with a steering wheel and with a lap belt. Figure 3 shows the setup of the whole dummy with the abdomen component within it, and with a lap belt attached. Figure 4 shows the picture of the dummy at the time of maximum penetration of the belt into the abdominal bag.

The objective of the model was to estimate the possible range of values for the foam stiffness and of the airbag volume which would result in responses similar to that seen for humans. Unfortunately there is only limited amount of information on the response of the human abdomen to impact loads from steering wheels [5,6]. Response to belt loading has been obtained essentially from testing with pigs [2]. All of these responses have been presented in the form of force-deflection curves at various impact speeds. The force is measured at the impactor and the deflection is the total deflection of the abdominal segment. The DYNAMAN model was set up so that the necessary displacements and forces were being generated. It is not possible to generate the force deflection curve directly within DYNAMAN, and the appropriate dynamic tables were imported into QuattroPro to generate the necessary curves as cross-plots.

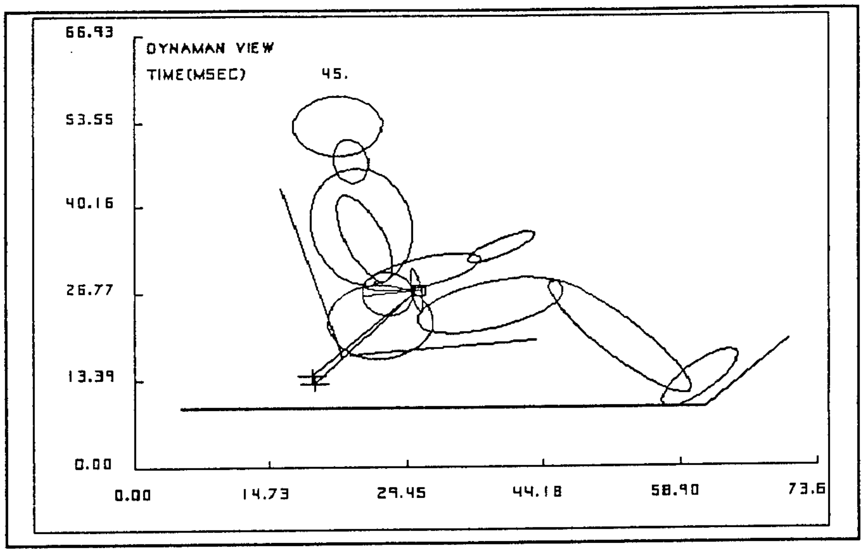


Figure 3. Model of a belted Hybrid III with abdomen component.

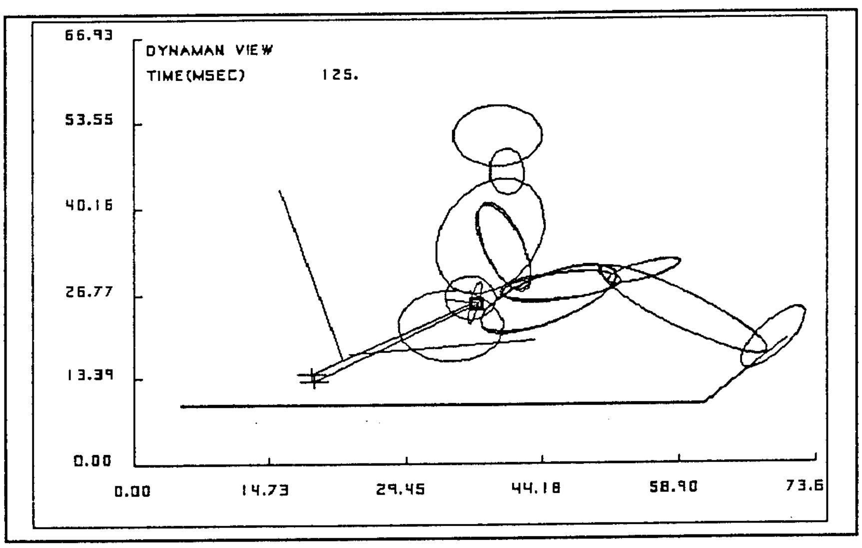


Figure 4. Model of Hybrid III with abdomen at time of maximum penetration.

A number of different approaches were taken in modelling the spring-damper system. Instead of a single spring-damper, a set of six spring-dampers were defined with the stiffness equally distributed amongst them. Such a model was built to verify the overall accuracy of the original model, and to provide a more detailed description of the deformation pattern across the front of the abdomen. Figure 5 shows an example of this model.

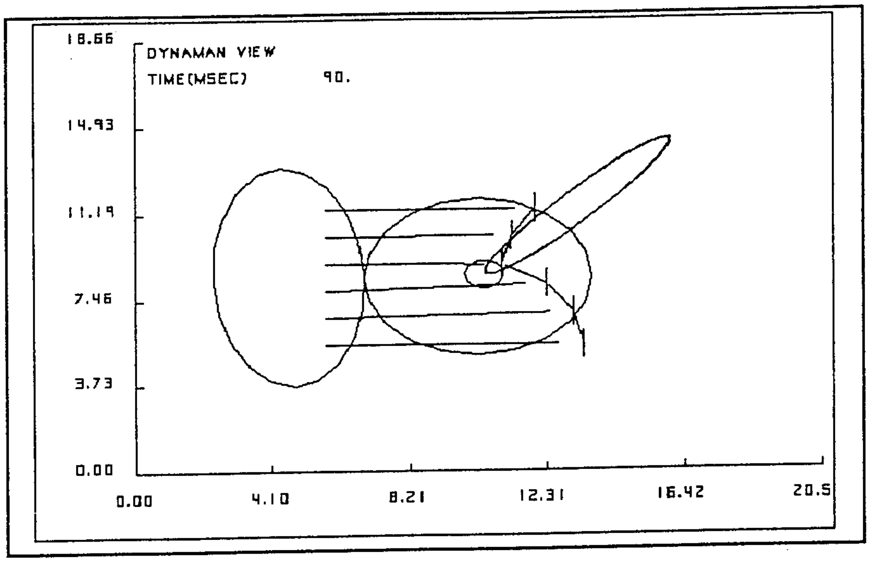


Figure 5. Multiple spring damper model at time of maximum penetration

Another simulation was undertaken by modelling the lap belt using as sequence of segments connected by free joints. This allowed the analysis of the response due to the extended surface of the belt, which is not feasible in the normal harness belt model. Figure 6 shows the setup of such a belt using seven segments. The belt surface was modeled using small planes which were connected by free pin joints. The ends of the surface were connected to the anchors by ordinary harness belt segments.

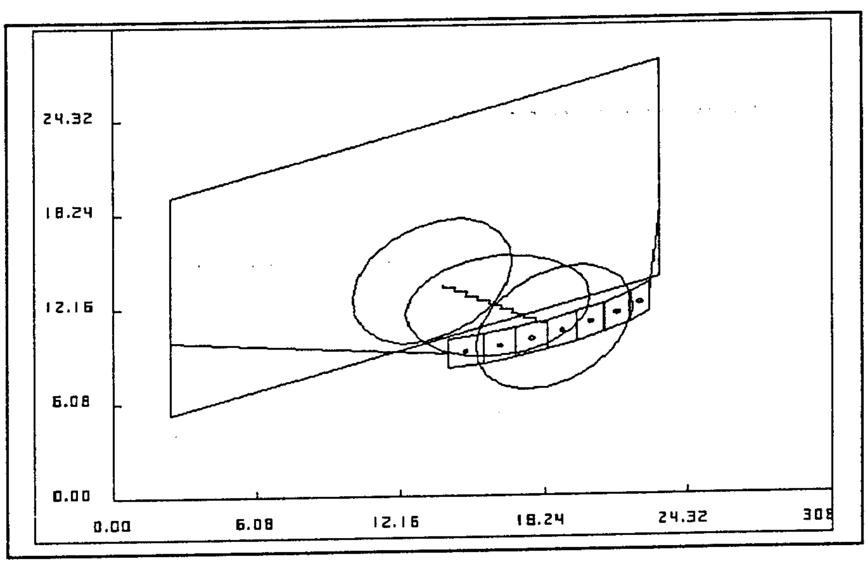


Figure 6. Lap belt modelled as sequence of planes

The simulations showed that the results when the belt was modelled using planes and when it was modelled as a regular

harness belt, were quite comparable. There was some discrepancy between the model using a single spring-damper and that using multiple spring-dampers. The difference appeared to arise from the multiple contacts which were generated between the impacting surface and the small planes that were defined to represent the front surface of the bag cover. This calculation overestimated the total force acting on the impactor, though the overall deflection was about the same in both models. It was felt that the model using a single spring-damper would be accurate enough for deciding on the range of foam stiffness that would be necessary in the design. Figure 7 is a comparison of the results from an early simulation and from a test using a foam-filled bag abdomen. The test results were used as a means of validating the results of the simulation, before extensive design changes were performed. As part of the analysis, a simple analytic calculation was also made of the relative contributions of the foam and the airbag to the stiffness of the response. The calculations were based on simple energy balance, where the initial kinetic energy of the impactor was distributed between the deformation energies of the foam and the bag. The foam deformation energy was based on its elastic and damping properties, while the airbag deformation energy was calculated using the first law of thermodynamics for a perfect gas.

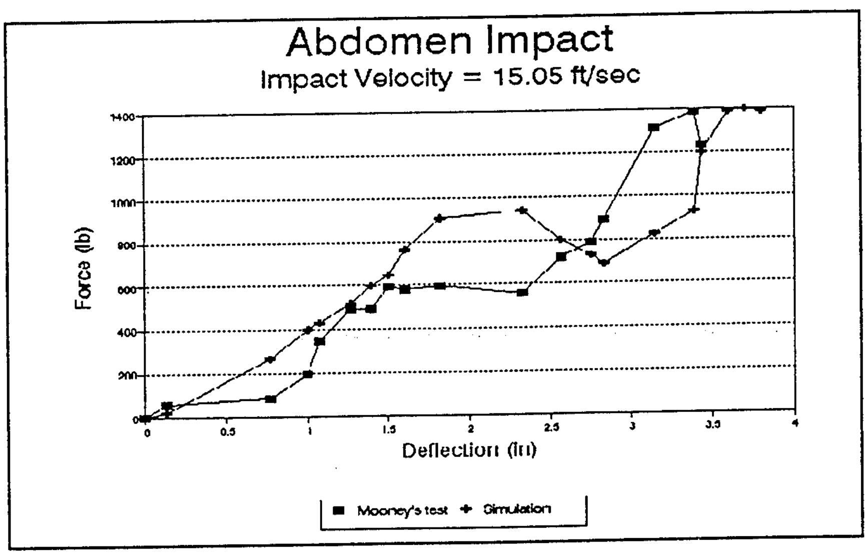


Figure 7. Comparison of abdomen simulation and test.

The different kinds of design changes that were possible using the model were:

- Volume of airbag
- Stiffness of foam
- Use of a single or two airbags
- Mass of cover

3. Neck Modelling

A new neck has been developed by the Vehicle Research Test Center (VRTC), based on a finite element model developed by EASI, which is more flexible than the Hybrid III neck [7]. The head/neck system has been tested under low to moderate acceleration pulses (8 - 15 G) in both the frontal and lateral directions and the head and neck angles appear to come close to the corridors that have been established from volunteer testing [8,9]. Figure 8 shows the general setup of the new neck. It consists of five aluminum disks separated by five butyl rubber disks. The rubber disks are elliptical in shape and have variable sizes for their semiaxes.

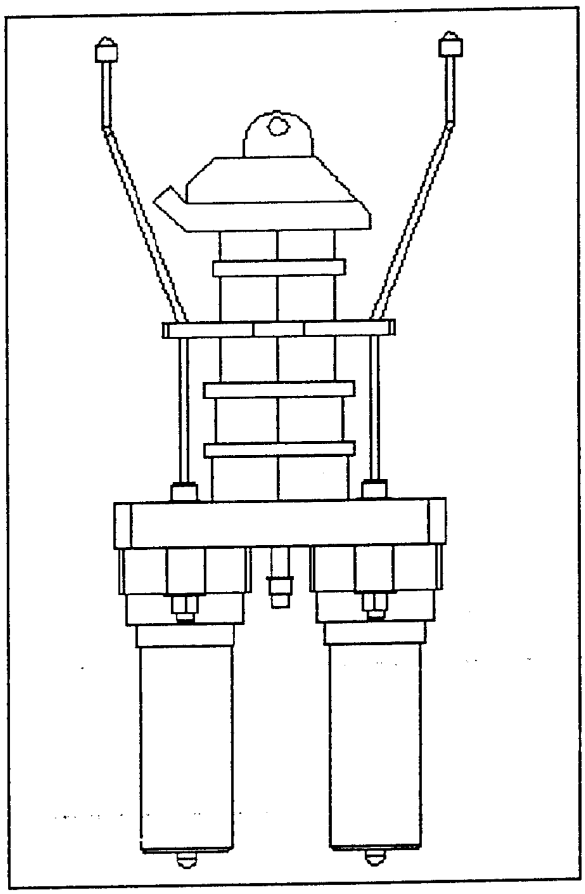


Figure 8. Setup of new neck.

One additional feature of the neck, are a pair of cables that are attached between the head and the base of the neck and a pair of spring coils that are attached to the end of each cable. DYNAMAN was used to develop a lumped mass model of the aluminum disks and the intermediate rubber disks. The neck has been developed and tested as a separate component, attached only to the head. As part of an effort to integrate the neck with the complete dummy and properly attach the neck to the thoracic spine, design changes which included changing the size of the disks were examined.

The basic model of the neck was built using five mass segments to represent the five aluminum disks. The aluminum disks were, for practical purposes, rigid segments and the bending of the neck was generated from the stiffness of the rubber disks. A simple pin joint was defined between adjacent segments. Two different models were developed to represent the stiffness of the neck during rotation. The first model was created using a pair of spring-dampers to represent each rubber disk. During the rotation of the neck, one of the springs would compress and one would extend which would represent the actual compression and tension on the two sides of each physical disk. In this model, the joints between the mass segments were free segments and all the stiffness was carried by the spring-dampers. The second model was based on assigning appropriate joint torques at the joint, without the recourse to spring-dampers.

A simple calculation procedure was used to come up with a rough estimate of the properties of the spring-dampers from the semiaxes of the individual disks and elastic moduli found from compression and tension tests on the disks. The procedure assumed a distributed compressive stress for a deformed disk proportional to the geometric deformation at the given location and then integrating over the area of the disk, to come up with a force-deflection relation. The damping coefficient was estimated based on the responses found from compression tests carried out at different loading rates. Such a scheme ignored the contribution of the shear stress and this was modeled by assuming a single multiplicative factor which could be used to fit the response at one acceleration pulse and one direction. The comparison of responses between test and simulation, for other pulses and directions would provide an evaluation of the efficacy of the model.

The joint torque function used in the joint torque model was based on finite element modelling that had been carried by EASI, which provided the joint torques as a function of angle for each of the disks. It was found that the joint torque model was not as efficient as the spring-damper model in predicting the head/neck response for different pulses and directions. In addition to modelling the rubber disks, the two cables were modelled using two harness belts. One end of each belt was anchored to the head, and the other end was connected to a small mass segment, which in turn was connected by a spring to the base of the neck. Each belt passed through a slip ring which modeled an eye in the central disk through which the cable passed. Figure 9 shows the setup of the neck model with spring-dampers.

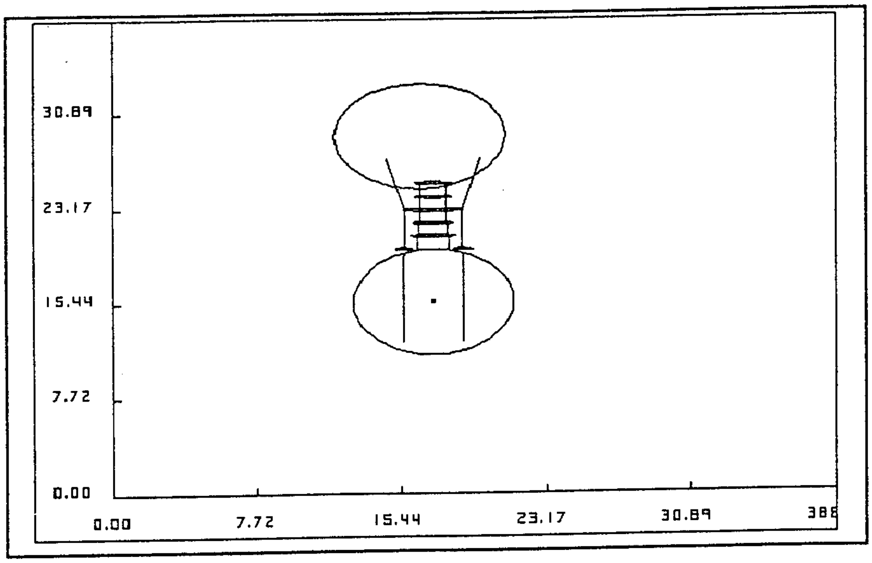


Figure 9. Model of neck using spring-dampers

As mentioned previously, the model was exercised by imposing frontal pulses of maximum magnitude of 8 G and 15 G and a lateral pulse of 7 G. The shapes of the pulses were basically half-sine waves. The behavior of the model under extension is also being examined, though the human response data under such loading is not as thoroughly documented. The output that was examined, were the head pitch angle and the neck angle. The measurement of the neck angle poses a special problem in these tests, since the actual neck is a flexible structure with variable rotation angles along the length of the neck. For these simulations, a standard location relative to the base of the neck was selected based on the length of the rotation axis found in the volunteer tests [8]. The angle made by a vector connecting this point to the occipital condyle (head/neck joint) was taken to be the neck angle. The angle was computed using QuattroPro, using as input the tables of angular displacement of the selected points generated by DYNAMAN. Figure 10 shows the head/neck system at the point of maximum flexion. Figure 11 shows a comparison of the output from one of these simulations with the volunteer data for the 8 G frontal pulse. As can be seen, the maximum head angle come fairly close to that of the volunteer average, but the maximum neck angle fall below.

A number of different design parameters are being varied in the neck model in order to understand the relative sensitivity of the response to these parameters and to help in selecting the parameters that can be successfully integrated into a revised neck model. The basic constraints in the design effort are the length of the neck which should be similar to the human neck (at least for the portion exposed above the thorax) and the attachment points to the head and thorax.

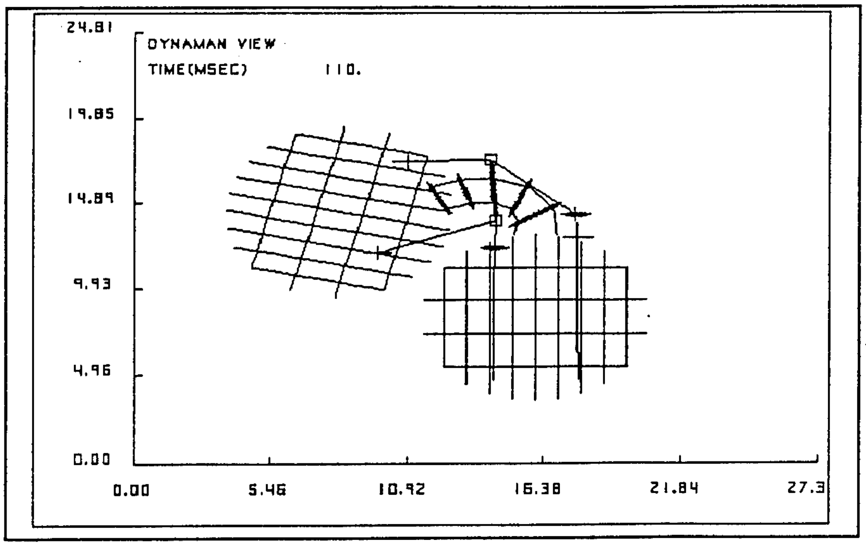


Figure 10. View of head/neck model at maximum flexion

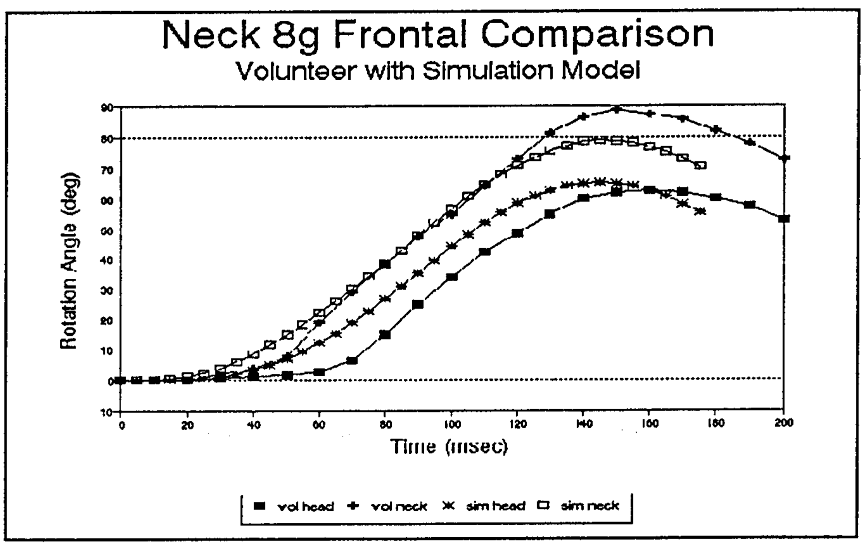


Figure 11. Comparison of head/neck angles from volunteer tests and simulation

The following areas of the model are being varied to examine their influence on the response:

- size of the rubber disks
- stiffness of the rubber disks
- number of rubber disks
- stiffness of spring attached to cable
- initial preload on cable spring

4. References

1. Eppinger, R., et. al., "Advanced Injury Criteria and Crash Evaluation Techniques," 14th International Technical Conference on Enhanced Safety of Vehicles, 144-152, 1994.
2. Rouhana, S.W., Viano, D.C., Jedrzecjak, E.A., and McCleary, J.D., "Assessing Submarining and Abdominal Injury Risk in the Hybrid III Family of Dummies," Proceedings of the 33rd Stapp Car Crash Conference. 257-278, 1989.
3. Mooney, M.T. and Collins, J.A., "Abdominal Penetration Measurement Insert for the Hybrid III Dummy," SAE Technical Paper 860653, 1986.
4. Ishiyama, S, Tsukada, K., Nishigaki, H., Ikeda, Y., Sakuma, S., Matsuoka, F., Kanno, Y., and Hayashi, S., "Development of an Abdominal Deformation Measuring System for Hybrid III Dummy," Proceedings of the 38th Stapp Car Crash Conference. 265-280, 1994.
5. Cavanaugh, J.M., Nyquist, G.W., Goldberg, S.J., and King, A.I., "Lower Abdominal Impact Tolerance," Proceedings of the 30th Stapp Car Crash Conference, 1986.
6. Nusholtz, G.S., Kaiker, P.S., Huelke, D.F., and Suggitt, B.R., "Thoraco-Abdominal Response to Steering Wheel Impacts," Proceedings of 29th Stapp Car Crash Conference, 221-267, 1985.
7. EASi Engineering, "Dummy Neck Design Support," Final Report, Contract No. DTNH22-92-D-07323, NHTSA, 1995.
8. Wismans, J., and Spenny, C.H., "Head-neck Response in Frontal Flexion," 28th Stapp Car Crash Conference, SAE Paper 841666, 1984.
9. Wismans, J., and Spenny, C.H., "Performance Requirements for Mechanical Necks in Lateral Flexion,", 27th Stapp Car Crash Conference, SAE Paper 831613, 1983.

ATB-V
GEBOD-IV.2
VIEW-III & IMAGE-I

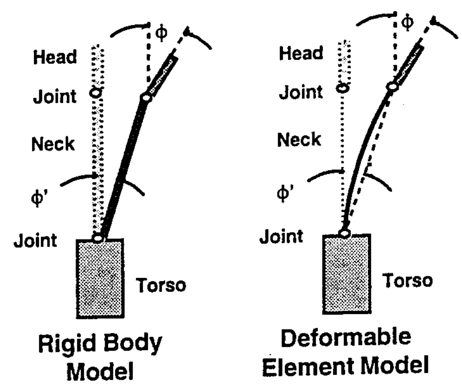
Louise Obergefell
Armstrong Laboratory
Wright-Patterson Air Force Base

ATB-V

- **Deformable Element Option**
- **Water Forces Analysis Capability (WAFAC)**
- **Robotic Joint Actuators**
- **Structured Output for Graphics Programs**
- **36 and 15 msec HIC**
- **Joint Function Use with Euler Joints**
- **General Code Portability Modifications**
- **New Manuals**

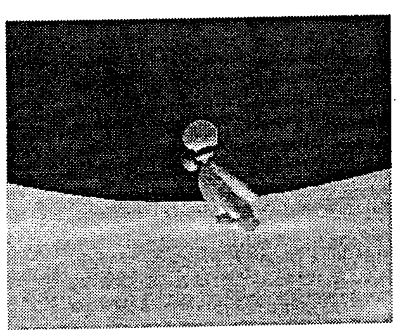
Deformable Element Option

- Dr. Hashem Ashrafiuon
- Interconnected Deformable & Rigid Bodies
- Uses Natural Frequencies & Normal Modes



WAFAC

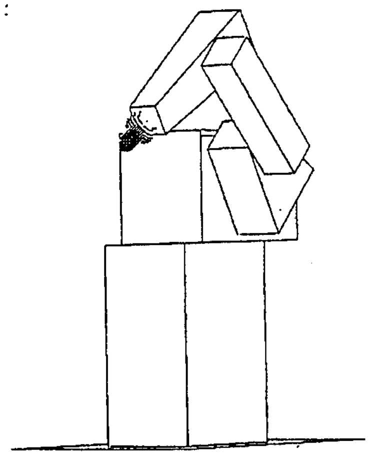
Water Forces Analysis Capability



- Developed for Coast Guard by GESAC, Inc.
- Body & Personal Flotation Device (PFD) Response to Water Forces
- Forces Include
  - Buoyancy
  - Wave Excitation
  - Added-Mass
  - Damping
  - Drag & Lift
- Still Water & Wave Conditions

Robotic Joint Actuators

- Active Driving Feature
- Joint Torques Dependent on Feedback
- User-Defined Feedback



Structured Output for Graphics Programs

- Compatability With VIEW, IMAGE, & DYNAMAN Postprocessor
- Reduced Size of ATB Output File
- Designed to Allow Easy Addition of New Graphics Capabilities

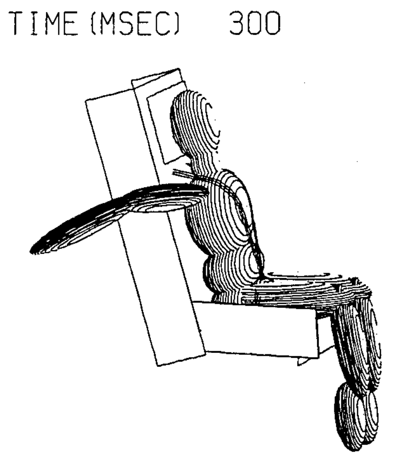
ATB Long-Term

- ✦ New Restraint Belt Model
- ✦ DYNAMAN Airbag
  - Developed by GESAC
- ✦ Advanced Contact Capabilities
  - Developed by GESAC
- ✦ Harness Belt Improvements

GEBOD-IV.2

- ✦ Improved Human Joint Properties
- ✦ Advanced Dynamic Anthropomorphic Manikin (ADAM) Data Set
- ✦ Supplement to Manual

VIEW-III

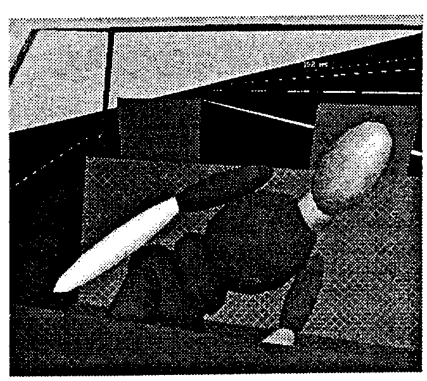


- Use Structured ATB Output
- Final Release
  - Program Will Be Maintained & Distributed
  - All Future Graphic Improvements Will Be Made To IMAGE
- New Manuals

IMAGE-I

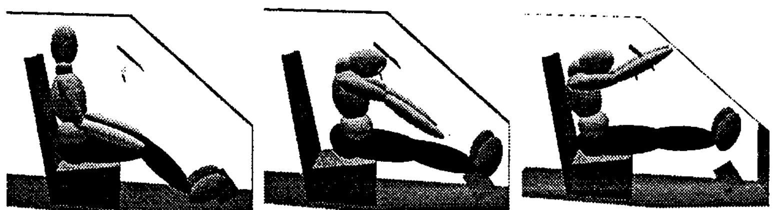
Interactively Manipulated ATB Graphics Environment (IMAGE)

- Currently Under Development
- Resides on Silicon Graphics Workstation
- Uses GL Libraries (Open GL in Future)
- Solid Model Graphics
- Easy Graphical Button & Mouse Interface
- Users' Manual



IMAGE

- Zoom & Viewing Angle Controlled Interactively
- Play Forwards, Backwards, or Step Frame
- Colors, Lighting, & Resolution Are Adjustable via Control File
- Reads Same Output File as VIEW
- Saves Images in rgb Format



Schedule

ATB-V	Fall 1996
GEBOD-IV.2	Winter 1995
VIEW-III	Spring 1996
IMAGE-I	1997

PRACTICAL ASPECTS OF MODELING WITH DYNAMAN & ATB

– KEITH FRIEDMAN
– FRIEDMAN RESEARCH
– SANTA BARBARA, CA

DYNAMAN

- INTERACTIVE PRE-PROCESSOR
- SIMULATION
- INTERACTIVE POST-PROCESSOR
- PROVIDES FOR SIGNIFICANTLY IMPROVED PRODUCTIVITY COMPARED WITH ATB

GENERAL CONSIDERATIONS

- DYNAMAN 3.0 WILL NOT RUN UNDER A DOS WINDOW
- FAMILIARITY WITH ATB FILE STRUCTURE IMPORTANT FOR USE OF DYNAMAN
- DYNAMAN HAS SIGNIFICANT OPPORTUNITIES FOR ENHANCEMENTS
- DYNAMAN IMPROVES PRODUCTIVITY

MODEL SETUP

DYNAMAN PREPROCESSOR

- EFFECTIVE AT EDITING VALUES IN EXISTING MODEL FILE (.DYN)
- EFFECTIVE AT LOADING IN EXISTING DATABASES AT INITIAL MODEL FILE SETUP

SETTING UP MODEL

- MODEL SETUP CAN BE MUCH EASIER WITH DYNAMAN
- STILL NEED TO KNOW ATB FILE LAYOUT
- SOME NUANCES
  - ADDING NEW SEGMENTS
  - ADDING ADDITIONAL PULSES
  - INCORRECT VALUES

ADDING SEGMENTS

- INTERACTIVELY ADDING NEW SEGMENTS
  - IF THE G CARDS ARE NOT REFERENCED TO 0, MAY HAVE TO MANUALLY CHANGE THE REFERENCE NUMBERS
  - USING MULTIPLE PULSES, CORRECT THE PULSE REFERENCES NUMBERS

ADDING SEGMENTS

- FILE READ TO ADD NEW SEGMENTS
  - MAY HAVE TO CORRECT REFERENCES FOR MULTIPLE PULSES, ENVIRONMENT AND CONTACTS

OPTIONS FILE SEGMENT MOTION EVRNMNT FUNCTN CONTACT SETUP RUNINFO EXIT

OCCUPANT INFO

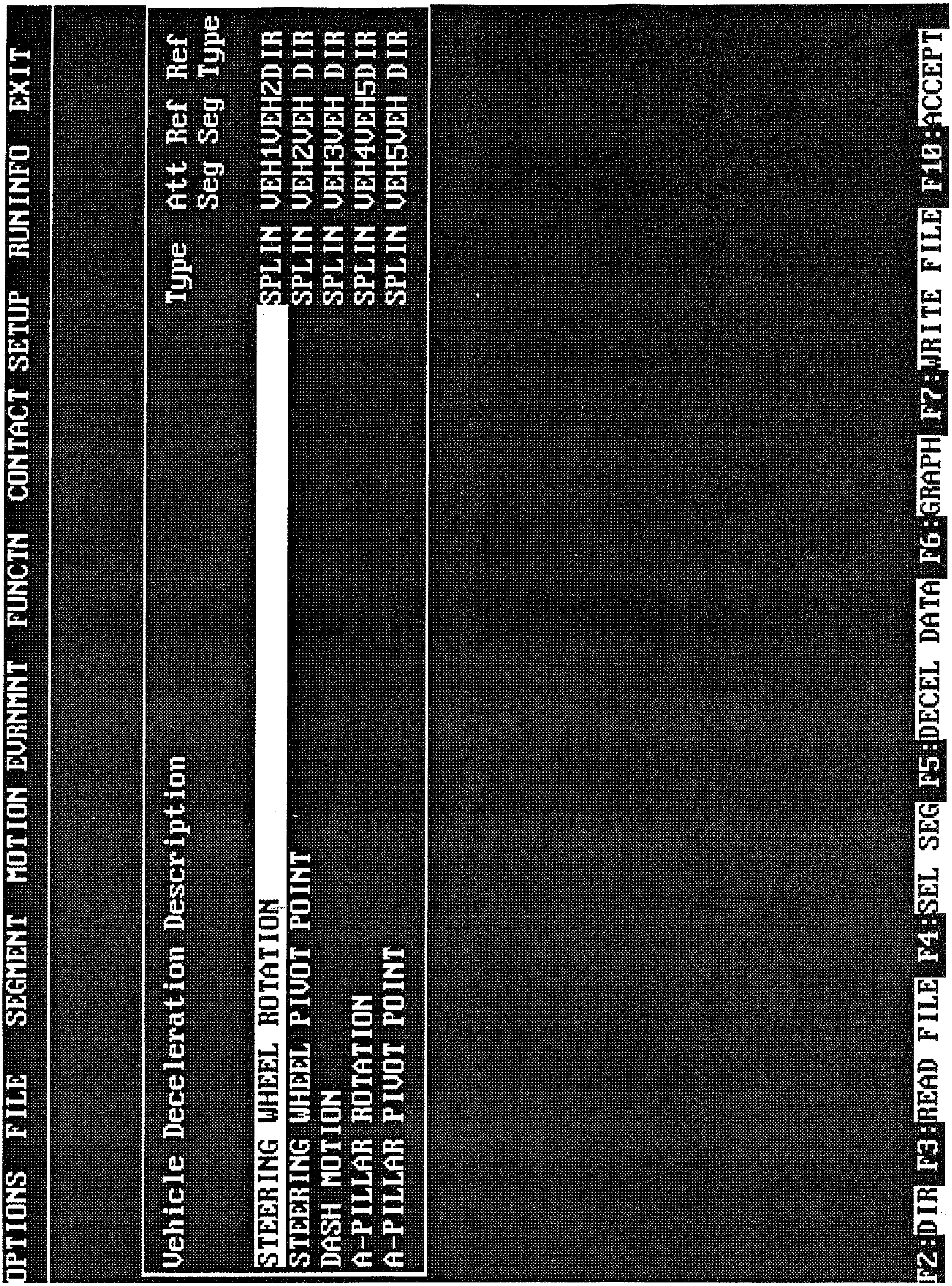
Description EXAMPLE FILE

No. of Seg 17 No. of Jnts 16

OK

Seg. Name	Prev. Seg.	Flxbl.	Seg Wt	Ixx	Iyy	Izz
RUA	UT	NO	5.061	0.1470	0.1470	.02218
RLA	RUA	NO	5.433	0.2846	0.2846	.01861
LUA	UT	NO	5.061	0.1470	0.1470	.02218
LLA	LUA	NO	5.433	0.2846	0.2846	.01861
S.W.	VEH1	NO	20.00	1.000	1.000	1.000
APIL	VEH4	NO	100.0	1.000	1.000	1.000
NEW1	VEH3	NO	1.000	0.1000	0.1000	0.1000

F2:SEL PREV SEG F10:ACCEPT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Vehicle Deceleration Description
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Att Seg
Ref Seg
Ref Type
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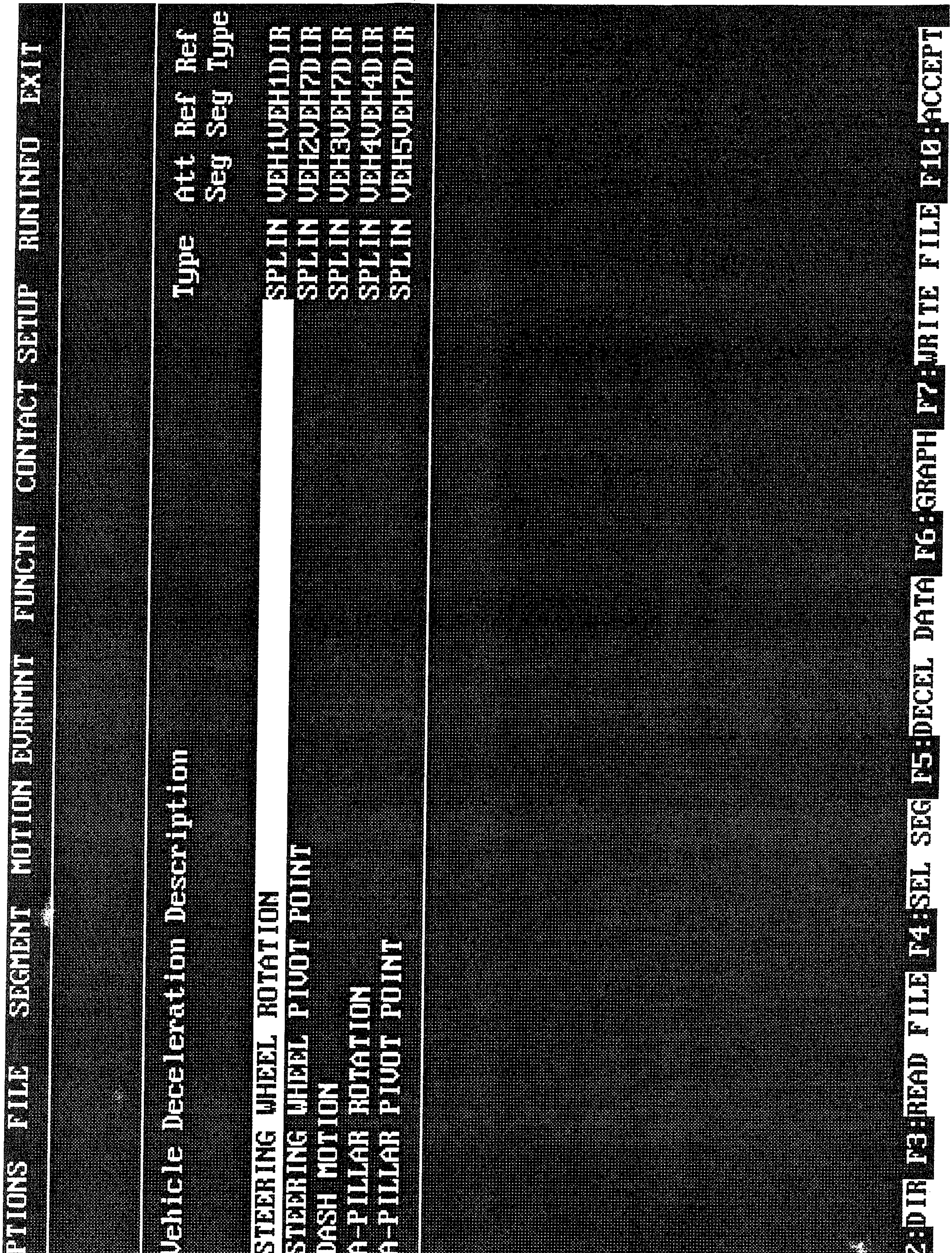
STEERING WHEEL PIVOT POINT SPLIN VEH2 VEH DIR
DASH MOTION SPLIN VEH3 VEH DIR
A-PILLAR ROTATION SPLIN VEH4 VEH5 DIR
A-PILLAR PIVOT POINT SPLIN VEH5 VEH DIR
F2:DIR F3:READ FILE F4:SEL SEG F5:DECEL DATA F6:GRAPH F7:WRITE FILE F10:ACCEPT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Att Seg
Ref Seg
Ref Type
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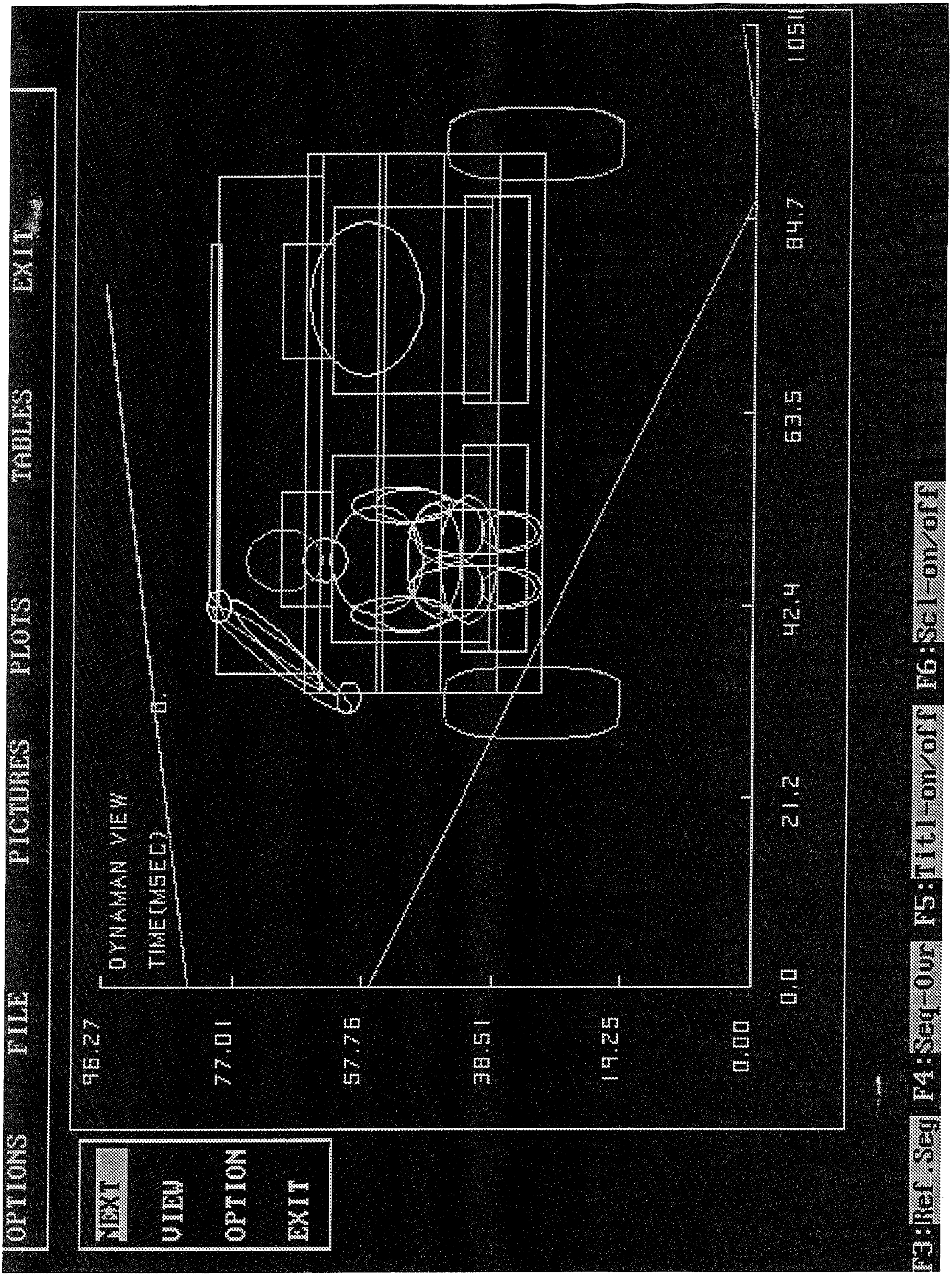
DASH MOTION SPLIN VEH3VEH7DIR
A-PILLAR ROTATION SPLIN VEH4VEH4DIR
A-PILLAR PIVOT POINT SPLIN VEH5VEH7DIR
F2:DIR F3:READ FILE F4:SEL SEG F5:DECEL DATA F6:GRAPH F7:WRITE FILE F10:ACCEPT

MULTIPLE PULSES

- MODELING INTRUSION OR OTHER MOTIONS
- EFFECT OF ADDING A PULSE IS NOT HANDLED BY DYNAMAN IF THERE ARE SEGMENTS WHICH HAVE A NON 0 REFERENCE IN THE G CARDS
- CHANGING A PLANE REFERENCE MUST BE DONE BOTH IN CONTACT AND ENVIRONMENT SECTIONS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FILE
PICTURES
PLOTS
TABLES
EXIT
NEXT
VIEW
OPTION
EXIT
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TIME(MSEC)
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57.76
38.51
19.25
0.00
0.0
21.2
42.4
63.5
84.7
105
F3:Ref.Seq
F4:Seq-Our
F5:Titl-on/off
F6:Scl-on/off

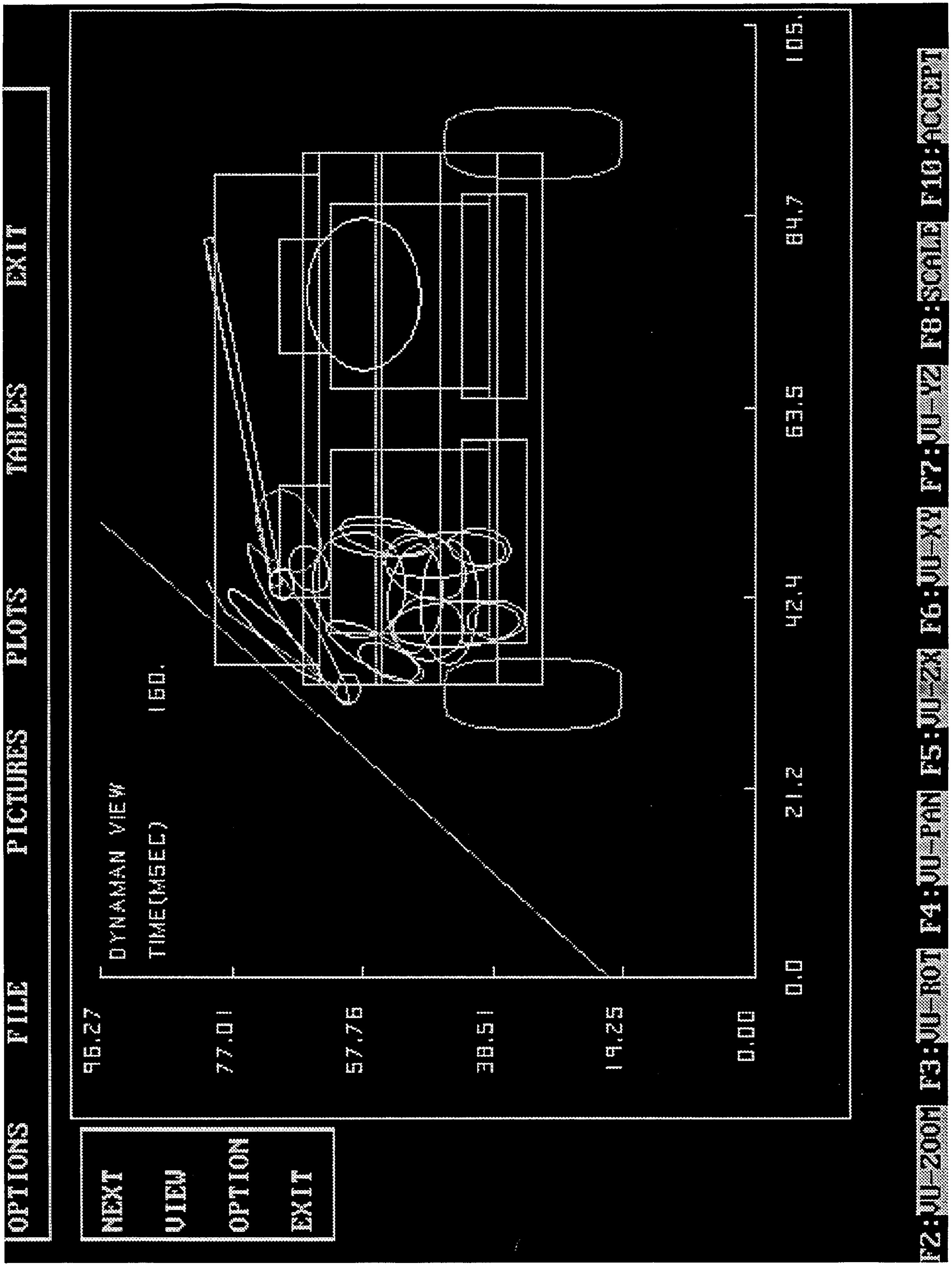
SPLINE MODEL FOR MOTIONS

- IF YOU USE EDSMAC FOR POSITION INPUTS USE A TOOL TO CHECK THE ACCELERATIONS ASSOCIATED WITH THE DISPLACEMENTS; SMOOTH THE DATA TO ENSURE THAT WILD OSCILLATIONS IN ACCELERATION ARE NOT OCCURRING.
- USE VELOCITY PULSES WHEN POSSIBLE

HYPER-ELLIPSOIDS

DYNAMAN

- KEEP POWERS 10 OR LESS IN DYNAMAN TO KEEP POST-PROCESSOR HAPPY
- USE EVEN POWERS
- KEEP RATIOS OF SEMI-AXES LOW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PICTURES
PLOTS
TABLES
EXIT
NEXT
VIEW
OPTION
EXIT
DYNAMAN VIEW
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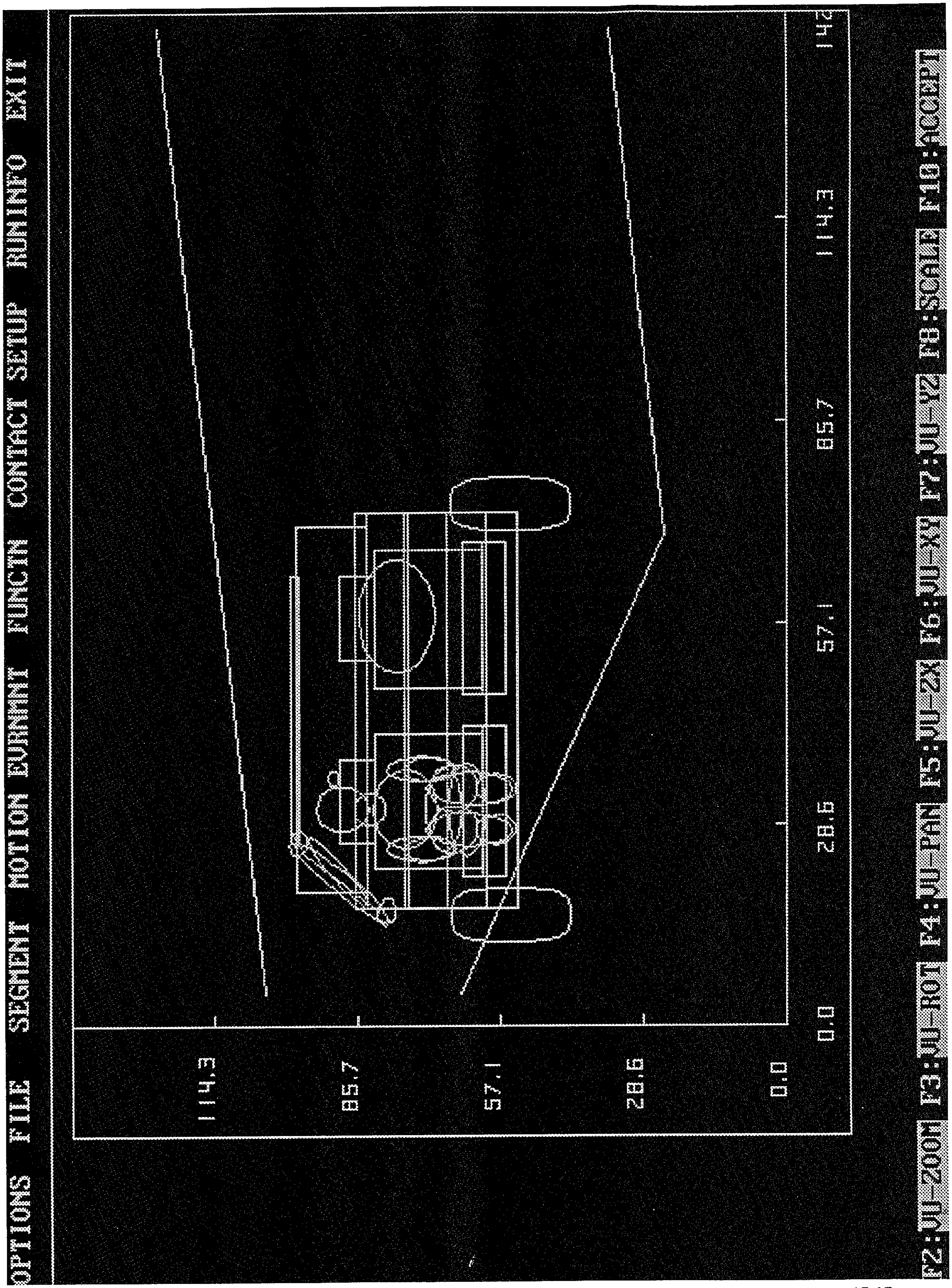
77.01
57.76
38.51
19.25
0.00
0.0
21.2
42.4
63.5
84.7
105.
F2:VU-ZOOM
F3:VU-ROT
F4:VU-PAN
F5:VU-ZX
F6:VU-XY
F7:VU-YZ
F8:SCALE
F10:ACCEPT

MODEL SETUP

- DYNAMAN PROVIDES FOR INTERACTIVE POSITIONING OF SEGMENTS AND PLANES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28.6
57.1
85.7
114.3
142
F2:VU-ZOOM F3:VU-ROT F4:VU-PAN F5:VU-ZX F6:VU-XY F7:VU-YZ F8:SCALE F10:ACCEPT

EQUILIBRIUM CHECKING

DYNAMAN

- FORCE BALANCING DOES NOT TAKE INTO ACCOUNT:
  - JOINT TORQUES
  - SEGMENT TO SEGMENT FORCES
  - SEGMENT TO SUPPLEMENTAL ELLIPSOIDS

HARNESS NDP PROBLEMS

- OFTEN ASSOCIATED WITH HARNESS
  - ADD MORE CONTACTS TO BODY
  - ADJUST PREFERRED DIRECTION VECTORS
  - MAKE TIME INCREMENTS SMALLER
  - ELIMINATE SHARP ANGLES FROM LAY

MODEL SETUP

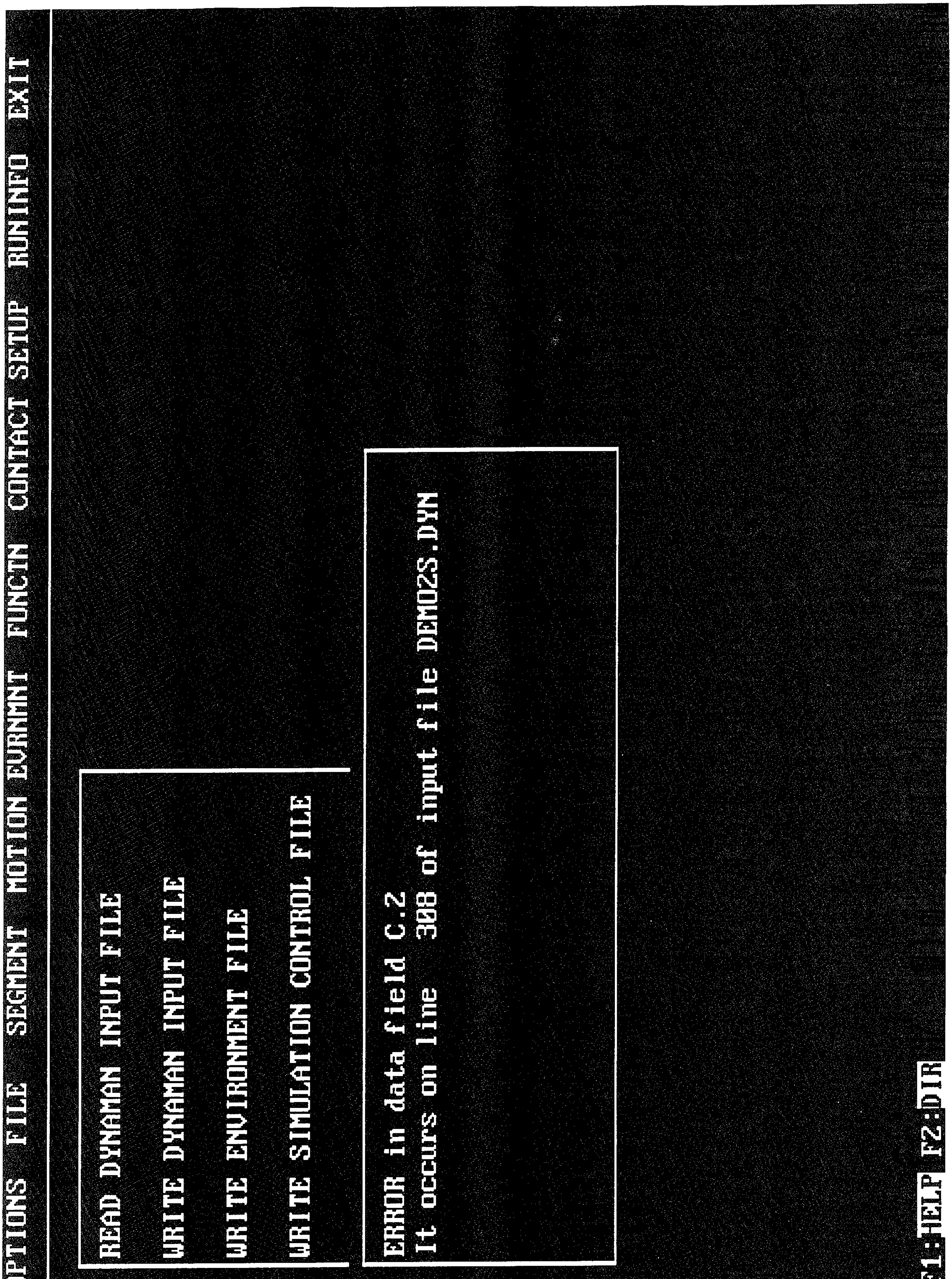
DYNAMAN PREPROCESSOR

- LACK OF VALIDITY CHECKING BEFORE MODEL FILE (.DYN) IS WRITTEN OUT BY PRE-PROCESSOR REPRESENTS A SIGNIFICANT OPPORTUNITY FOR PRODUCTIVITY IMPROVEMENT

RUNNING MODEL

PERFORMANCE COMPARISON

- DYNAMAN & ATB RUN ABOUT SAME SPEED ON A 486
- DYNAMAN ON PENTIUM 90 ABOUT 2.8 TIMES FASTER THAN A 486-DX50
- DYNAMAN NOT COMPILED FOR PENTIUM INSTRUCTION SET
- ATB COMPILED FOR PENTIUM INSTRUCTION SET SHOULD RUN FASTER


OPTIONS FILE SEGMENT MOTION EVRNMNT FUNCTN CONTACT SETUP RUNINFO EXIT
READ DYNAMAN INPUT FILE
WRITE DYNAMAN INPUT FILE
WRITE ENVIRONMENT FILE
WRITE SIMULATION CONTROL FILE
ERROR in data field C.2
It occurs on line 308 of input file DEMO2S.DYN
F1:HELP F2:DIR

NDP EXCEPTIONS

- HARNESS PROBLEMS
- INCORRECT VALUE PROBLEMS

NDP EXCEPTIONS INCORRECT VALUES

- CHECK FOR ALL 0'S IN SEGMENT INERTIA'S OR WEIGHTS
- CHECK FOR ALL ZERO'S IN JOINT TORQUE & VISCOUS VALUES

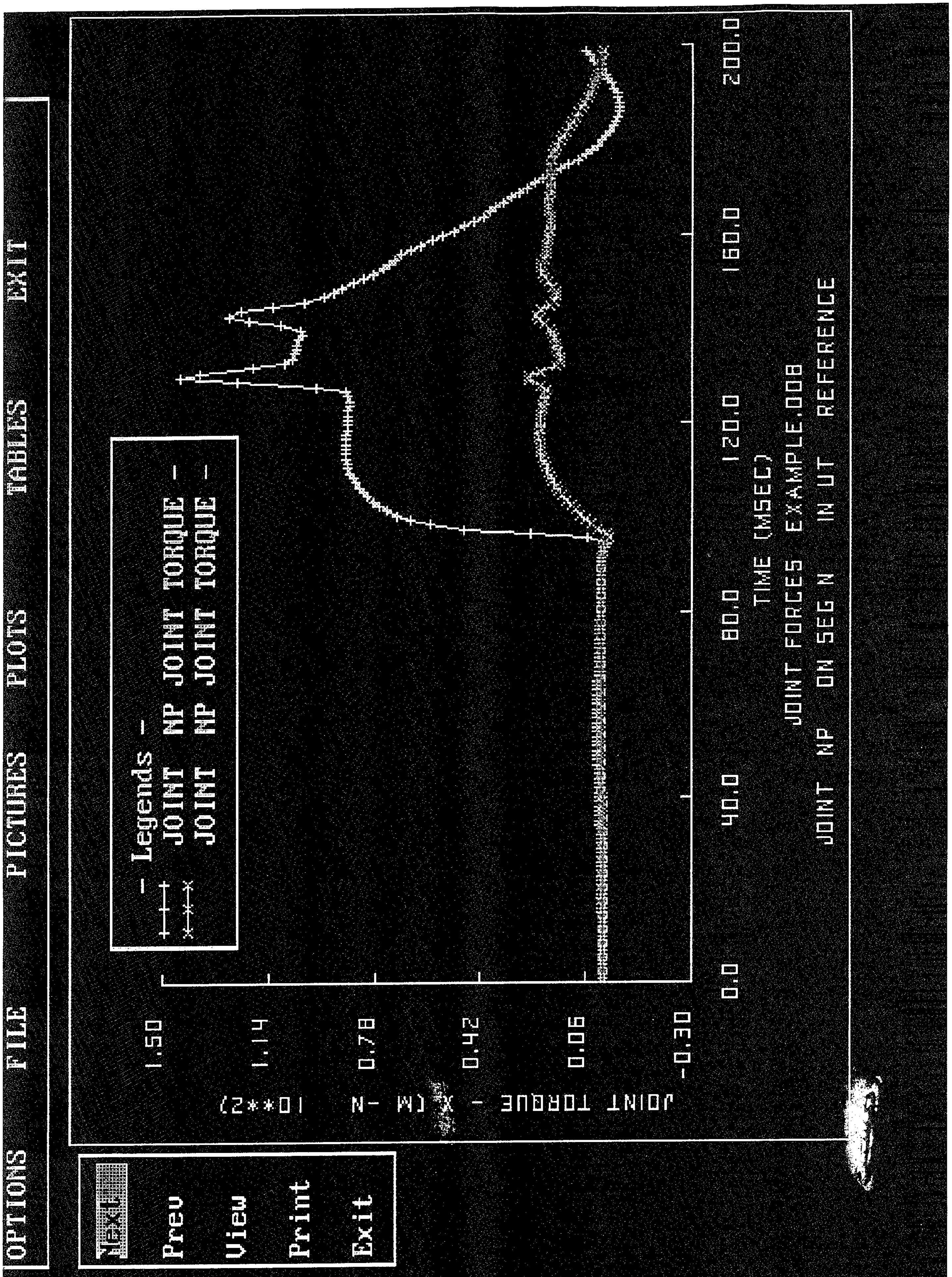
```
DYNAMAN SIMULATION PROGRAM

Version 3.0, June 1992

Input File: NEWTX.DYN

Completed Iteration Step      6

Program terminated. PDAUX negative sqrt. H < HMIN+EPS8. Rerun program with
smaller HMIN on input Card A.4.
Error Code:    31

STOP: DYNAMAN FATAL ERROR
```

PRESENTING OUTPUT

- DYNAMAN OUTPUT PLOTS & PICTURES EASY TO USE AND INTERACTIVE
- DYNAMAN OUTPUT GENERALLY IMPROVED COMPARED WITH VIEW EXCEPT FOR HIDDEN LINES AND FRAME
- MANY OPPORTUNITIES FOR IMPROVEMENTS

DYNAMAN PLOTTING

- SELECT FROM FULL RANGE OF OUTPUT DATA AVAILABLE
- COMPARISON PLOTS BOTH WITHIN AND BETWEEN RUNS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PICTURES
PLOTS
TABLES
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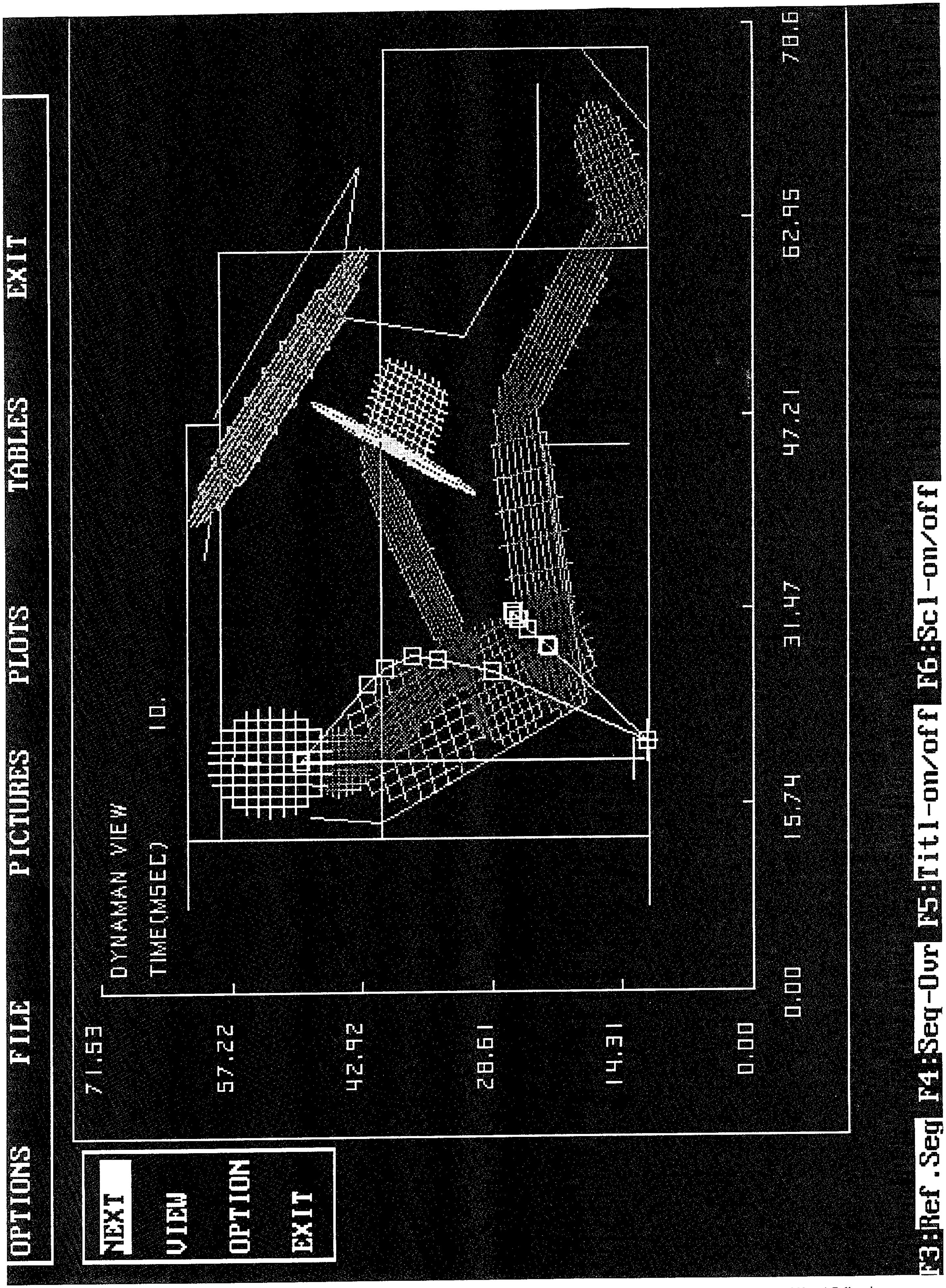
Next
Prev
View
Print
Exit
- Legends -
JOINT NP JOINT TORQUE -
JOINT NP JOINT TORQUE -
1.50
1.14
0.78
0.42
0.06
-0.30
JOINT TORQUE - X (M - N 10**2)
0.0
40.0
80.0
120.0
160.0
200.0
TIME (MSEC)
JOINT FORCES EXAMPLE.008
JOINT NP ON SEG N IN UT REFERENCE

DYNAMAN OUTPUT

PICTURE GRAPHICS

- FLEXIBLE & EASY TO USE
- CHANGE VIEWS & ROTATIONS WITH A COUPLE OF KEY STROKES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PLOTS
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NEXT
VIEW
OPTION
EXIT
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28.61
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0.00
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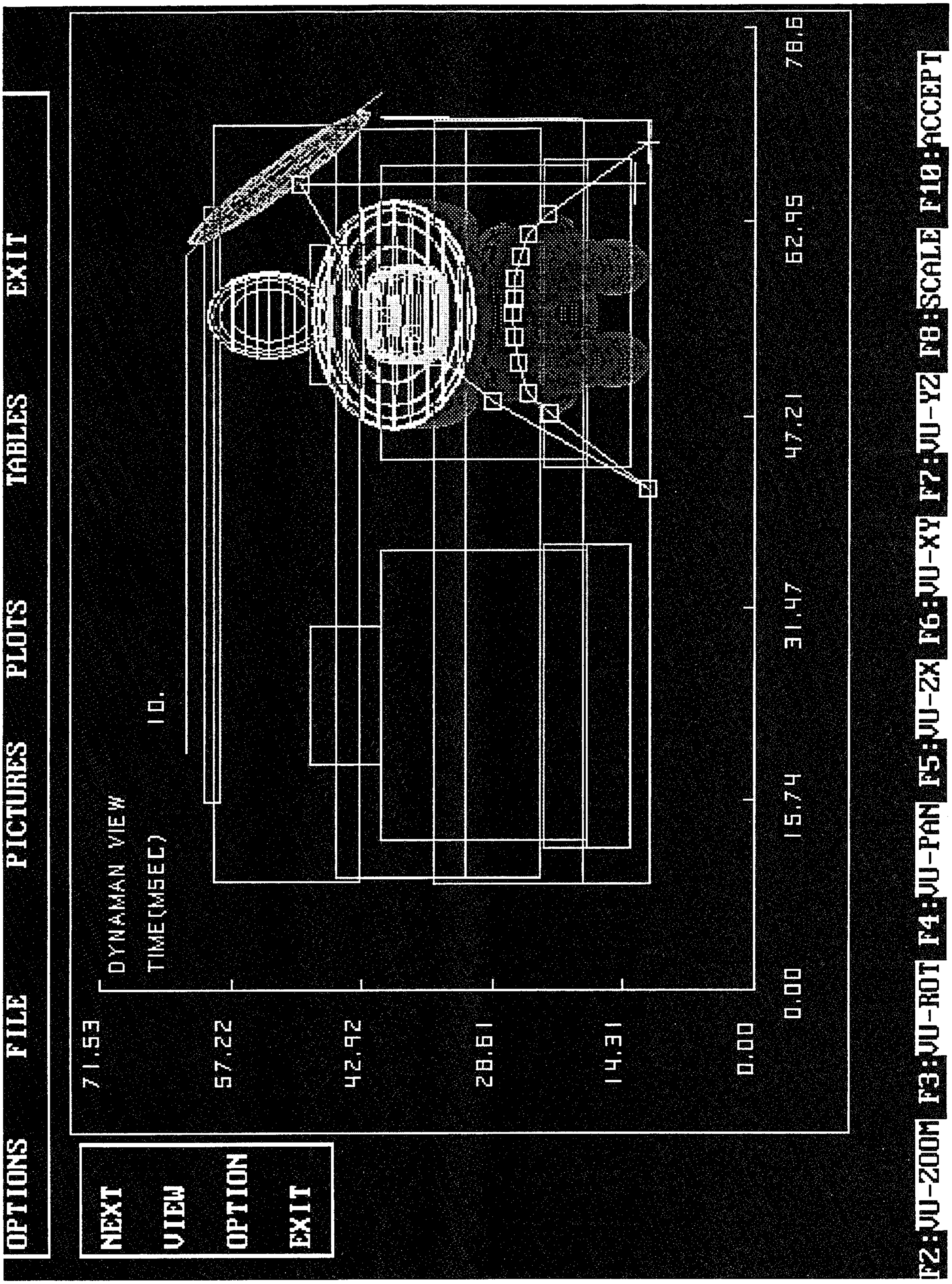
OPTIONS FILE PICTURES PLOTS TABLES EXIT
NEXT
VIEW
OPTION
EXIT
DYNAMAN VIEW
TIME(MSEC) 10.
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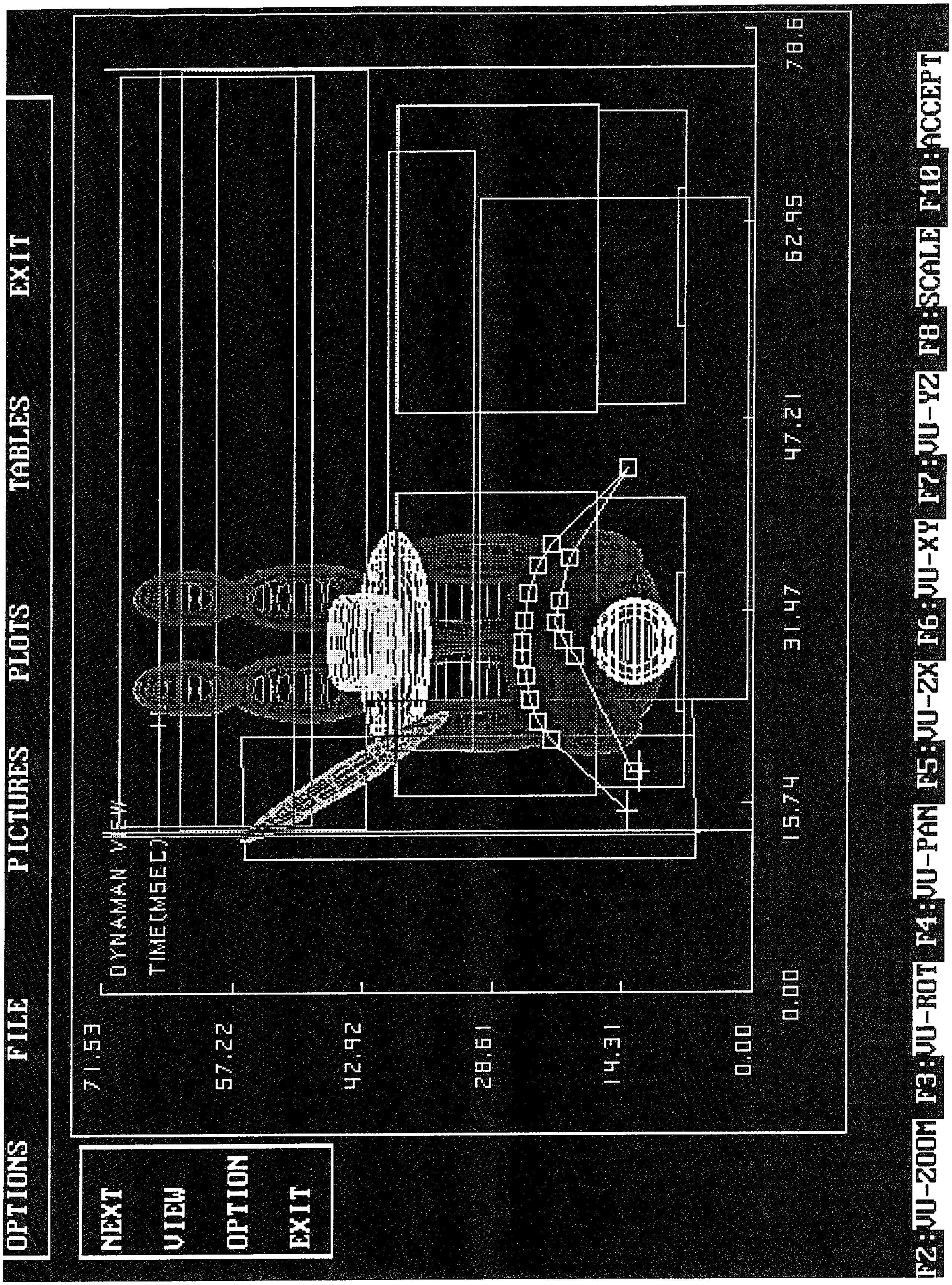
42.92
28.61
14.31
0.00
0.00 15.74 31.47 47.21 62.95 78.68
F2:VU-ZOOM F3:VU-ROT F4:VU-PAN F5:VU-ZX F6:VU-XY F7:VU-YZ F8:SCALE F10:ACCEPT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VIEW
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28.61
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0.00
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31.47
47.21
62.95
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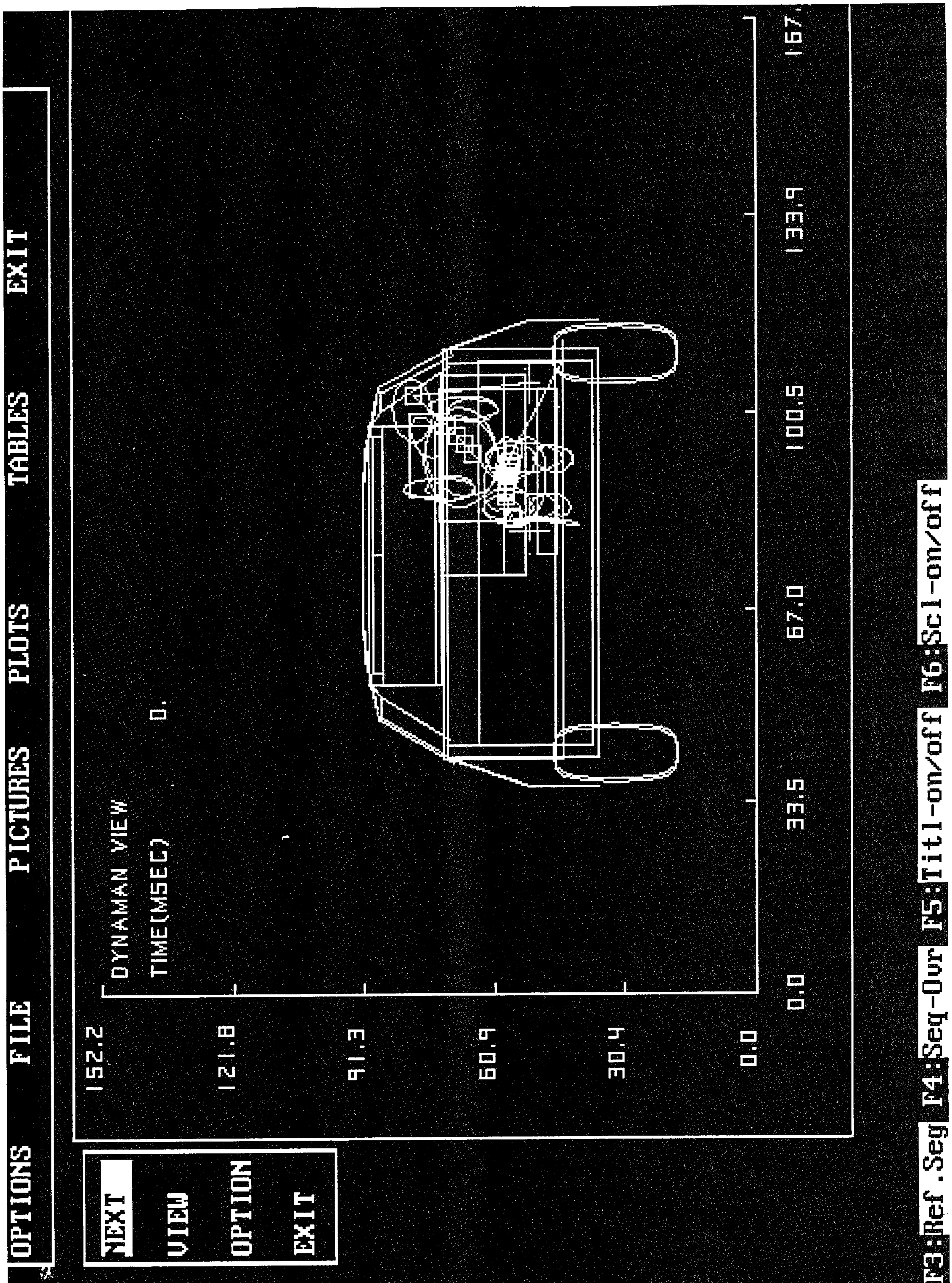
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DYNAMAN VIEW
TIME(MSEC) 0.
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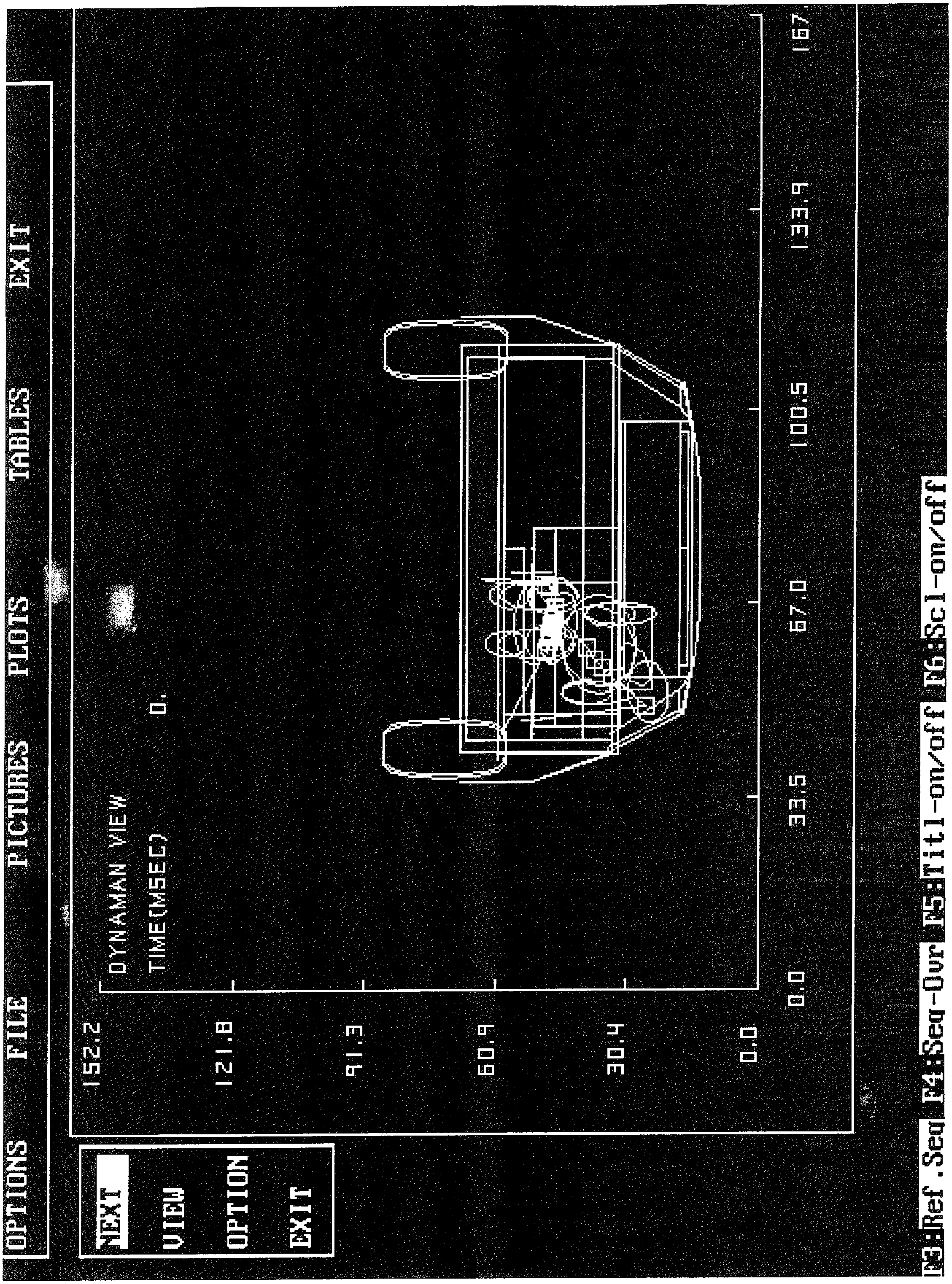
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PLOTS
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60.9
30.4
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0.0
33.5
67.0
100.5
133.9
167.
F3:Ref.Seq F4:Seq-Ovr F5:Titl-on/off F6:Scl-on/off

DYNAMAN OUTPUT

PICTURE GRAPHICS

- REFERENCES FOR SUPPLEMENTAL ELLIPSES TYPICALLY HAVE TO BE CORRECTED EACH TIME IN UNLESS .ENV USED
- FOR LARGE PROBLEMS OVERLAYING PICTURES MAY NOT FUNCTION
- SINGLE PIXEL LINES DO NOT REPRODUCE WELL ON VIDEO WITHOUT FUZZY FUNCTION

DYNAMAN OUTPUT

AIRBAGS

- IF USING 3 OR MORE AIRBAGS USE CARE IN EXAMINING PLOT AND TABLE OUTPUT

DYNAMAN OUTPUT

OUTPUT TABLES

- CARE SHOULD BE USED LOOKING AT ROLL AND YAW COLUMNS; SOMETIMES THEY CAN BE REVERSED.

DYNAMAN OUTPUT

DYNAMAN GRAPHICS OPPORTUNITIES

- PERSPECTIVE 3D SOLID GRAPHICS ARE NEEDED ON THE PC FOR FINAL OUTPUT
- DXF OR OTHER OUTPUT FILE WITH ELLIPSE & PLANE SIZE AND POSITION INFO (INCLUDING PLANE POSITIONS ACCOUNTING FOR STACKED PULSE MOTIONS) NEEDED TO CONNECT WITH BETTER GRAPHICS OUTPUT

SOME NEEDS & RECOMMENDATIONS

- VALIDITY CHECKING IN PREPROCESSOR PRIOR TO WRITING OUT FILE
- BETTER DIAGNOSTICS FOR PREFERRED DIRECTION ISSUES
- EXPANDED LIMITS AND BOUNDS CHECKING TO SUPPORT LARGE PROBLEMS
- 3D FINAL PRESENTATION GRAPHICS
- SOFTWARE MAINTENANCE CHARGE

SUMMARY

- DYNAMAN PROVIDES IMPROVED PRODUCTIVITY
- KNOWLEDGE OF ATB INPUT FILE IS PRESENTLY ESSENTIAL
- SIGNIFICANT OPPORTUNITIES FOR ENHANCEMENT OF DYNAMAN ARE AVAILABLE

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